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DIELECTRIC CONSTANT AND LOSS DATA

Laboratory for Insulation Research
Massachusetts Institute of Technology
Cambridge, MA 02139

December 1980

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INTERIM REPORT FOR PERIOD JANUARY 1977 - MAY 1980

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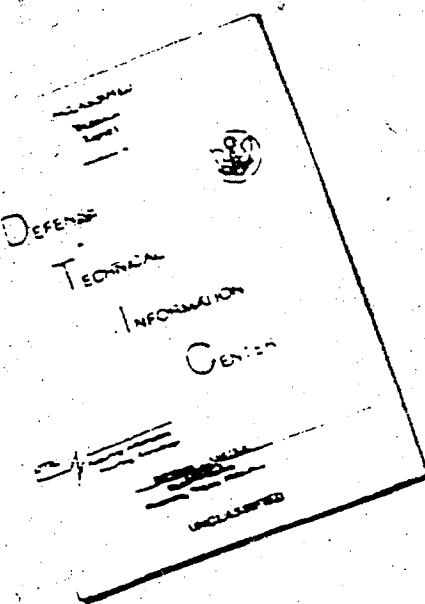
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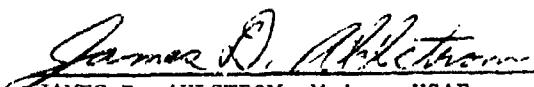


JOHN C. OLSON
Project Engineer
Laser Hardened Materials Branch



WILLIAM R. WOODY, Acting Chief
Laser Hardened Materials Branch
Electromagnetic Materials Division

FOR THE COMMANDER



JAMES D. AHLSTROM, Major, USAF
Acting Chief
Electromagnetic Materials Division
Materials Laboratory

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PREFACE

The dielectric constant and loss data presented in this report were measured at the Laboratory for Insulation Research of the Massachusetts Institute of Technology, Cambridge, Massachusetts, by W. B. Westphal. This work was performed between 1 January 1977 and 15 May 1980 under Contract F33615-77-C-5063, Project No. 7514, Task No. 24230104 for the Materials Laboratory of the Air Force Wright Aeronautical Laboratories.

This report was submitted by the author for publication in August 1980.

The work was administered under direction of the AF Materials Laboratory, with Mr. John C. Olson (AFWAL/MLPJ) acting as project engineer.

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SUMMARY

The first sections of this report describe changes in measurement techniques and programming of calculations.

A technical report dated December 1975 presents data on materials measured in the early part of this contract. A later data report is dated May 1977. The index following the data section refers to early data reports and uses the prefix 10- for pages of the present report.

The data section does not generally include measurements on research samples under development by or for the Air Force Materials Laboratory.

MEASUREMENT TECHNIQUE

The basic measurement techniques using bridges, reentrant cavities, standing waves, and dielectric-filled cavities have been discussed in previous reports.^{1-7*} During the present contract period the only new type of measurements has been for high loss liquids: the use of a glass or plastic capillary tube mounted in a plane one-quarter wavelength from the short in the standing wave system. The tube axis is parallel to the electric field in either rectangular or circular hollow waveguide. This method was used for water-acid solutions, liquid ammonia and sulfur.

PROGRAMMING

Program 1, in the following section, is used for calculating the dielectric constant and loss of a sample in a capillary tube. The input data:

DS	node width, sample in
SN	node position, sample in
CONC	specified acid concentration
NC	number of measurements
DG	node width, empty capillary
GN	node position, empty capillary
R	inner radius of capillary
FGH	frequency, GHz
C	conversion factor between capillary admittance and waveguide admittance at the same plane
C1	initial guess for correction term in K1 due to loss, Iteration finds exact correction
WLG	wavelength in air filled waveguide
SMF	conversion factor to calculate conductivity from loss factor

*References

1. Tech. Rep. 182 Lab. Ins. Res., Contract AF33(616)-8353, October 1963.
2. " " 201 " " " " October 1966.
3. AFML-TR-66-28, " " " " AF33(615)-2199, January 1966.
4. AFML-TR-70-138, " " " " F33615-67C-1612, July 1970.
5. AFML-TR-71-66, " " " " F33615-70C-1220, April 1971.
6. AFML-TR-74-250, Pt. II, Lab. Ins. Res., Contract F33615-71-C-1274,
December 1975
7. AFML-TR-74-250, Pt. III, " " " Contract F33615-75-C-5020,
May 1977

Program 1 High Loss Liquid in Capillary

FORTRAN IV G1 RELEASE 2.0

```

0001      REAL*8 TWO,WL,FGH,PII3,PII4,WLG,XOG,DELN,TANG,EG,DG,XOS,GN,SN,
0002      2TANS,THETA,DS,ES,K1M,K2M,K1,K2,C1,KM,KMA,KMB,K1CAL,K2CAL,ERROR,
0003      3WE,K1OLD,K2OLD,EROLD,SMF,SIGMA,CONC,R,C,STEP(4)/.03D0,.01D0,
0004      4.003D0,.001D0/,F(2)/1.D0,-1.D0/,FAKE(2),FUN(2),ONE
0005      COMPLEX*16 ZONE,ZDNE,TWOC,YG,YT,KMAC,KMBC,GR,D2C,D3C,D4C,D5C,
0006      2D6C,D7C,J11,J12,J13,J14,J1,J01,J02,J03,J04,J0,RATIO,K1C,K2C,KCOR,
0007      3YG1,YG2,YG3,YG4,YT2,YT3,YT4,YS,KC
0008      EQUIVALENCE (FAKE(1),YS),(FUN(1),KCOR)
0009      DIMENSION DS(40),SN(40),CDNC(40),DATE(39)
0010      NAMELIST/IN/DS,SN,CONC,NC/CONST/DG,GN,DELN,R,FGH,C,C1,WLG,SMF
0011      200 FORMAT (1X,39A2)
0012      201 FORMAT(1HO,20X,39A2,/)
0013      100 FORMAT(1X,7HWT%ACID,5X,2HK1,3X,9HJUNCOR. K1,5X,2HK2,3X,
0014      29HUNCOR. K2,3X,12HS^GMA MHO/CM,1X,5HERROR,10X,3HJ04,10X,3HJ14)
0015      101 FORMAT(F7.3,1X,F8.2,1X,F8.2,3X,F8.2,2X,F8.2,3X,F9.5,1X,
0016      2E9.2,1X,E9.2,1X,E9.2,1X,E9.2,1X,E9.2)
0017      102 FORMAT(5X,2HDS,10X,2H$N,10X,4HCONC,BX,1H)
0018      103 FORMAT(1X,F10.4,1X,F10.4,1X,F10.4,8X,I2)
0019      104 FORMAT(3X,13HKOUNT FOR K1*,1X,I2)
0020      105 FORMAT(3X,13HKOUNT FOR K2*,1X,I2)
0021      77 READ(5,200,END=88) DATE
0022      WRITE(6,201) DATE
0023      READ(5,IN)
0024      READ(5,CONST)
0025      WRITE(6,102)
0026      DO 8 I=1,NC
0027      WRITE(6,103) DS(I),SN(I),CONC(I),I
0028      8 CONTINUE
0029      ZONE=(1.D0,0.D0)
0030      ZDNE=(0.D0,1.D0)
0031      ONE=1.D0
0032      TWO=2.D0
0033      TWOC=ZONE*TWO
0034      WL=2.997924562D1/FGH
0035      PII3=6.2831853072D0/WL
0036      PII4=6.28318D0/WLG
0037      WRITE(6,CONST)
0038      WRITE(6,100)
0039      XOG=WLG/4.D0-DELN
0040      TANG=DTAN(PII4*XOG)
0041      EG=PII4*DGTWO
0042      YG=(ZDNE*(-C))*(ZONE-ZDNE*(EG*TANG))/((ZONE*EG)-(ZDNE*TANG))
0043      DO 10 I=1,NC
0044      XOS=XOG-(GN-SN(I))
0045      TANS=DTAN(PII4*XOS)
0046      THETA=PII4*DS(I)/TWO
0047      ES=DSIN(THETA)/DSQRT(TWO-(DCOS(THETA))**2)
0048      YT=(ZDNE*(-C))*(ZONE-ZDNE*(ES*TANS))/((ZONE*ES)-(ZDNE*TANS))
0049      YS=YT-YG
0050      K1M=FAKE(1)
0051      K2M=-FAKE(2)
0052      K1M=K1M+ONE
0053      K1=K1M+C1*K2M
0054      K2=K2M
0055      KM=DSQRT(K1**2+K2**2)
0056      KMA=DSQRT((KM-K1)/TWO)*PII3*R
0057      KMB=DSQRT((KM+K1)/TWO)*PII3*R
0058      KMAC=ZONE*KMA
0059      KMBC=ZONE*KMB
0060      GR=KMBC+KMAC
0061      D2C=ZONE*16.D0
0062      D3C=ZONE*384.D0
0063      D4C=ZONE*1.8432D4
0064      D5C=ZONE*4.D0
0065      D6C=ZONE*64.D0
0066      D7C=ZONE*2304.D0
0067      J11=GR/TWOC
0068      J12=GR**3/D2C
0069      J13=GR**5/D3C
0070      J14=GR**7/D4C

```

Program 1, continued

```

0064      J1=J11+J12+J13+J14
0065      J01=ZONE
0066      J02=GR**2/D5C
0067      J03=GR**4/D6C
0068      J04=GR**6/D7C
0069      J0=J01+J02+J03+J04
0070      RATIO=(TWOC/GR)*J1/J0
0071      K1C=ZONE*K1
0072      K2C=ZONE*(-K2)
0073      KC=K1C+K2C
0074      KCOR=KC*RATIO
0075      K1CAL=FUN(1)
0076      K2CAL=-FUN(2)
0077      ERROR=DSQRT((K1M-K1CAL)**2+(K2M-K2CAL)**2)
0078      DO 400 K1,4
0079      DO 600 J=1,2
0080      WE=ONE+STEP(K)*F(J)
0081      KOUNT=0
401      K1OLD=K1
0082      KOUNT=KOUNT+1
0083      EROLD=ERROR
0084      K1=K1*WE
0085      KM=DSQRT(K1**2+K2**2)
0086      KMA=DSQRT((KM-K1)/TWO)*PII3*R
0087      KMB=DSQRT((KM+K1)/TWO)*PII3*R
0088      KMAC=ZONE*KMA
0089      KMBC=ZONE*KMB
0090      GR=KMBC+KMAC
0091      D2C=ZONE*16.D0
0092      D3C=ZONE*384.D0
0093      D4C=ZONE*1.8432D4
0094      D5C=ZONE*4.D0
0095      D6C=ZONE*64.D0
0096      D7C=ZONE*2304.D0
0097      J11=GR/TWOC
0098      J12=GR**3/D2C
0099      J13=GR**5/D3C
0100      J14=GR**7/D4C
0101      J1=J11+J12+J13+J14
0102      J01=ZONE
0103      J02=GR**2/D5C
0104      J03=GR**4/D6C
0105      J04=GR**6/D7C
0106      J0=J01+J02+J03+J04
0107      RATIO=(TWOC/GR)*J0/J0
0108      K1C=ZONE*K1
0109      K2C=ZONE*(-K2)
0110      KC=K1C+K2C
0111      KCOR=KC*RATIO
0112      K1CAL=FUN(1)
0113      K2CAL=-FUN(2)
0114      ERROR=DSQRT((K1M-K1CAL)**2+(K2M-K2CAL)**2)
0115      IF(KOUNT.GT.20) GO TO 601
0116      IF(ERROR.LE.EROLD) GO TO 401
0117      K1=K1OLD
0118      ERROR=EROLD
0119      600  CONTINUE
0120      GO TO 602
0121      601  WRITE(6,104) KOUNT
0122      602  DO 700 J=1,2
0123          WE=ONE+STEP(K)*F(J)
0124          KOUNT=0
421      K2OLD=K2
0125      KOUNT=KOUNT+1
0126      EROLD=ERROR
0127      K2=K2*WE
0128      KM=DSQRT(K1**2+K2**2)
0129      KMA=DSQRT((KM-K1)/TWO)*PII3*R
0130      KMB=DSQRT((KM+K1)/TWO)*PII3*R
0131
0132

```

Program 1, continued

```

0133      GR=KMBC+KMAC
0134      D2C=ZONE*16.00
0135      D3C=ZONE*384.00
0136      D4C=ZONE*1.8432D4
0137      D5C=ZONE*4.00
0138      D6C=ZONE*64.00
0139      D7C=ZONE*2304.00
0140      J11=GR/TWOC
0141      J12=GR**3/D2C
0142      J13=GR**5/D3C
0143      J14=GR**7/D4C
0144      J1=J11+J12+J13+J14
0145      J01=ZONE
0146      J02=GR**2/D5C
0147      J03=GR**4/D6C
0148      J04=GR**6/D7C
0149      J0=J01+J02+J03+J04
0150      RATIO=(TWOC/GR)*J1/J0
0151      K1C=ZONE*K1
0152      K2C=ZONE*(-K2)
0153      KC=K1C+K2C
0154      KCOR=KC*RATIO
0155      K1CAL=FUN(1)
0156      K2CAL=-FUN(2)
0157      ERROR=DSQRT((K1M-K1CAL)**2+(K2M-K2CAL)**2)
0158      IF(KOUNT.GT.20) GO TO 701
0159      IF(ERROR.LE.EROLD) GO TO 421
0160      K2=K2OLD
0161      ERROR=EROLD
0162      700 CONTINUE
0163      GO TO 702
0164      701 WRITE(6,105) KOUNT
0165      702 IF(ERROR.LE.1.0-4) GO TO 450
0166      400 CONTINUE
0167      450 SIGMA=SMF*K2
0168      WRITE(6,101) CONC(I),K1,K1M,K2,K2M,SIGMA,ERROR,J04,J14
0169      10 CONTINUE
0170      GO TO 77
0171      88 CALL EXIT
0172      END

```

Output

3GHZ 21.3 DEG.C.

DS	SN	CUNC	I
0.0679	0.3032	0.0	1
0.2009	0.3159	1.1090	2
0.6445	0.3835	5.0434	3
1.1360	0.5070	10.0760	4

&CONST

DG=.120000000000000002D-01,GN=.47999999999999996 ,DELN=.219700000000000006

R=.321730000000000002D-01,FGH=3.000000000000000 ,C=938.39999999999977
 C1=.15700000000000004D-01,WLG=13.855000000000000 ,SMF=.1566659999999998D-02
 &END

WT%ACID	K1	UNCOR. K1	K2	UNCOR. K2	SIGMA MHO/CM	ERROR
0.0	77.45	77.73	12.24	12.34	0.02041	0.24D-01
1.109	71.70	71.84	41.14	41.43	0.06856	0.33D-01
5.043	40.68	39.82	134.86	135.40	0.22477	0.19D-01
10.076	-12.93	-15.64	231.21	230.75	0.38534	0.11D+00

J04 J14
 -0.13D-07 0.65D-08 -0.17D-09 -0.27D-09
 -0.11D-09 0.17D-07 -0.37D-09 0.97D-10
 0.64D-07 -0.53D-07 0.24D-08 0.59D-09
 -0.62D-07 -0.37D-06 0.79D-08 -0.12D-07

Program 2 is used for calculating the results for a temperature run on a thin sample (in coax or hollow waveguide) located on a quarter-wavelength spacer. The variations in data with temperature of the empty sample holder with, and without, the spacer are expressed as a power series of temperature change from room temperature. Corrections can then be made for the change in electrical length of the spacer with temperature.

Partial notation follows:

DXQC	node width for holder with spacer only, corrected for temperature effects
DAC	node width for empty holder corrected for temperature
ANC	node position for empty holder versus temperature
QNC	node position for holder with spacer only corrected for changes with temperature
DQC	spacer length versus temperature
THC	sample thickness corrected for linear thermal expansion

Program 2. Thin Sample temp. run

FORTRAN IV G1 RELEASE 2.0

```

0001      INTEGER*4 I,J,K,N,NX
0002      REAL*8 PII,PII2,ONE,TWO,W,FC,W1,TANW1,DA,DT,THC,D,T,T0,TCD,LW02,
2LW,WL2,WL2,WC1,C2,TC6,K3,TANW2,TCW,DQC,DQ,TCQ,DAC,A5,A6,DXQC,
3DXQ,AQ,AQQ,DXQCC,ON,AN,TC1,TC2,TC3,ANC,QNC,TC7,TC8,TC9,TXQD,
4W2,PII3,U,TA1,DC,DX,SN,COSINE,TXOS,Z11RE,Z11IM,SILLY(2),AZ11,
5AZ16,A,B,FUN(2),TAHA,TANB,A2,B2,Z14RE,Z14IM,ERROR1,WE,BOLD,
GSTEP(5)/1.D-2,1.D-3,1.D-4,1.D-5,1.D-6/,F(2)/1.D0,-1.D0/,Z14I0D,
7Z14ROD,EROLD,AOLD,FCC,FAKE(2),RA,AIM,C1,TC6,C2,C3,KAPPA,TAND,L1,
8L2,L3,R,KAPPAC,TANDC,RE,TAM,SIGMA,PUN(2),DS,C1C,D2,D3,AX,WL1
COMPLEX*16 ZONE,ZZONE,X,Y,Z22,AL1D2,BE1D2,G1D2,Z4,Z10,Z11,Z16,
2Z12SQ,THG2D2,Z14,Z12RE,Z12IM,Z12NEW,Z13,G,H,Z15,Z17,G2D2,K3C,Z14R,
3Z14I
0004      DIMENSION DS(30),SN(30),D2(30),D3(30),DATE(39),AX(30),T(30)
0005      EQUIVALENCE (SILLY(1),Z4),(FAKE(1),Z15),(FUN(1),Z14),
2(PUN(1),Z12SQ)
0006      NAMELIST/CONST/DA,DX0,DQ,FC,LW,DT,TCW,TCQ,A5,A6,AQ,AQQ,TC1,TC2,T0,
2TC3,TC7,TCB,TC9,TCD,TC6,C1,C2,D,AN,QN/IN/DS,SN,1,D2,D3,AX,
3NX/OUT/A,B,AZ11,AZ16,Z12SQ,Z11,Z16
0007      200 FORMAT(1X,39A2)
0008      20. FORMAT(1H0,20X,39A2)
0009      220 FORMAT(1H0,5X,2HDS,8X,2H$N,6X,2HD2,7X,2HD3,7X,2H'X,8X,
24HTEMP,6X,1HI)
0010      230 FORMAT(2X,F8.4,1X,F8.4,2X,F7.4,2X,F6.4,2X,F8.5,2X,F8.2,2X,I2)
0011      100 FORMAT(1H0,5X,2HNS,6X,2HDS,4X,7HD,corr.,4X,2HFC,6X,1HB,6X,2HK1,
29X,2HK2,9X,3HTAN,15X,6HZ4/Z14//)
0012      300 FORMAT(2X,F7.4,2X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4,3X,F9.6,
23X,F9.6,3X,E13.6,2X,E13.6)
0013      301 FORMAT(10X,6HTEMP.=,F7.1,1X,6HDEG.C.,4X,6HSIGMA=,E11.4,6HMHO/CM,
25X,19HSAMPLE HOLDER DIA.=,F8.5)
0014      77 READ(5,200,END=88) DATE
0015      WRITE(6,201) DATE
0016      READ(5,CONST)
0017      READ(5,IN)
0018      WRITE(6,220)
0019      WRITE(6,230)(DS(I),SN(I),D2(I),D3(I),AX(I),T(I),I,I=1,NX)
0020      WRITE(6,CONST)
0021      WRITE(6,100)
0022      ZONE=(1.D0,0.D0)
0023      ZOCNE=(0.D0,1.D0)
0024      ONE=1.D0

```

Program 2, continued

```

0025      TWO=2.D0
0026      PII=3.1415926536D0
0027      PII2=TWO*PII
0028      W=ONE+FC
0029      W1=W
0030      TANW1=DA/(DT*W1)
0031      WL1=LW
0032      LW02=LW**2/W
0033      DO 10 I=1,NX
0034      THC=D*(ONE+(T(I)-T0)*TCD)
0035      IF(FC.GT.0.D0) GO TO 33
0036      WL2=LW
0037      WC2=1.D30

0038      GO TO 35
33      WC1=3.4125B6D0*1.27D0*C2
0040      WC2=WC1*(ONE+TC6*(T(I)-T0))
0041      WL2=DSQRT(LW02*WC2**2/(WC2**2-LW02))
0042      K3=WL2/(PII2*THC)
0043      W2=(WL2/WC2)**2+ONE
0044      TANW2=TANW1+DSQRT(ONE+TCW*(T(I)-T0))+W1/W2
0045      DQC=DQY*(ONE+TCQ*(T(I)-T0))
0046      DAC=DA*(ONE+A5*(T(I)-T0)+A6*(T(I)-T0)**2)
0047      DXQC=DXQ*(ONE+AQ*(T(I)-T0)+AQ*(T(I)-T0)**2)
0048      DXQCC=DXQC-DAC-(QN-AN)*W1*TANW1+DQC*W2*TANW2
0049      ANC=AN-TC1*(T(I)-T0)-TC2*(T(I)-T0)**TC3
0050      QNC=QN-TC7*(T(I)-T0)-TCB*(T(I)-T0)**TC9
0051      TXQOQ=DTAN(PII2*((QNC-ANC)/WL1-DQC/WL2))
0052      X=ZONE*(DXQCC*PII/WL2)
0053      Y=ZOOONE*(-TXQOQ)
0054      ZB2=(X*Y)/(ZONE+X*Y)
0055      PII2=PII2/WL2
0056      U=W2-ONE
0057      TA1=DSORT(ONE+(TANW2/(ONE-U/(1.00054D0+W2))**2)
0058      AL1D2=ZONE*(PII3*DSQRT(5.D-1*(1.00054*W2-U)*(TA1-ONE))*THC)
0059      BE1D2=ZOOONE*(PII3*DSQRT(5.D-1*(1.00054*W2-U)*(TA1+ONE))*THC)
0060      G1D2=AL1D2+BE1D2
0061      DC=DQC+THC
0062      DX=DS(I)-DXQC-(SN(I)-QN)*W1*TANW1+DC*W2*TANW2
0063      COSINE=DCOS(PII*DX/WL2)**2
0064      X=DSIN(PII*DX/WL2)/DSQRT(AX(I)-COSINE)
0065      TXOS=DTAN(PII2*((SN(I)-ANC)/WL1-DC/WL2))
0066      Y=ZOOONE*(-TXOS)
0067      Z4=(X*Y)/(ZONE+X*Y)
0068      Z10=ZOOONE/K3
0069      Z11=Z10/Z4
0070      Z11RE=SILLY(1)
0071      Z11IM=SILLY(2)
0072      Z16=(1.D0/3.D0)*Z11**2
0073      Z12SQ=CDOSQRT(Z11+Z16)
0074      AZ11=CDABS(Z11)
0075      AZ16=CDABS(Z16)
0076      A=PUN(1)
0077      B=PUN(2)
0078      IF(0.D0.LT.B) GO TO 160
0079      WRITE(6,OUT)
0080      B=1.D0
0081      160 TAHA=DTANH(A)
0082      TANB=DTAN(B)
0083      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
0084      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
0085      THG2D2=ZONE*A2+ZONE*B2
0086      G2D2=ZONE*A+ZONE*B
0087      Z14=(ZONE+G1D2*THG2D2/(ZB2*G2D2))/(ZONE/ZB2+G2D2*THG2D2/G1D2)
0088      Z14RE=FUN(1)
0089      Z14IM=FUN(2)
0090      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)

```

Program 2, continued

```

0091      DO 400 K=1,5
0092      TAHA=DTANH(A)
0093      DO 600 J=1,2
0094      WE=ONE+STEP(K)*F(J)
0095      401 BOLD=B
0096      Z14IOD=Z14IM
0097      Z14ROD=Z14RE
0098      EROLD=ERROR1
0099      B=B*WE
0100      TANB=DTAN(B)
0101      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
0102      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
0103      THG2D2=ZONE*A2+ZOOONE*B2
0104      G2D2=ZONE*A+ZOOONE*B
0105      Z14=(ZONE+G1D2*THG2D2/(ZB2*G2D2))/(ZONE/ZB2+G2D2*THG2D2/G1D2)
0106      Z14RE=FUN(1)
0107      Z14IM=FUN(2)
0108      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
0109      IF(ERROR1.LE.EROLD) GO TO 401
0110      Z14IM=Z14IOD
0111      Z14RE=Z14ROD
0112      B=BOLD
0113      ERROR1=EROLD
0114      600 CONTINUE
0115      TANB=DTAN(B)
0116      DO 700 J=1,2
0117      WE=ONE+STEP(K)*F(J)
0118      402 AOLD=A
0119      Z14ROD=Z14RE
0120      Z14IOD=Z14IM
0121      EROLD=ERROR1
0122      A=A*WE
0123      TAHA=DTANH(A)
0124      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
0125      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
0126      THG2D2=ZONE*A2+ZOOONE*B2
0127      G2D2=ZONE*A+ZOOONE*B
0128      Z14=(ZONE+G1D2*THG2D2/(ZB2*G2D2))/(ZONE/ZB2+G2D2*THG2D2/G1D2)
0129      Z14RE=FUN(1)
0130      Z14IM=FUN(2)
0131      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
0132      IF(ERROR1.LE.EROLD) GO TO 402
0133      Z14RE=Z14ROD
0134      Z14IM=Z14IOD
0135      A=AOLD
0136      ERROR1=EROLD
0137      700 CONTINUE
0138      IF(ERROR1.LE.1.D-6) GO TO 450
0139      400 CONTINUE
0140      450 Z12RE=ZONE*A
0141      Z12IM=ZOOONE*B
0142      Z12NEW=(Z12RE+Z12IM)**2
0143      K3C=K3*ZONE

0144      Z13=-Z12NEW*K3C**2
0145      FCC=U
0146      G=ZONE*FCC
0147      H=ZONE*W2
0148      Z15=(G+Z13)/H
0149      Z14R=ZONE*Z14RE
0150      Z14I=ZOOONE*Z14IM
0151      Z14=Z14R+Z14I
0152      Z17=Z4/Z14
0153      RA=FAKE(1)
0154      AIM=FAKE(2)
0155      C1C=C1*(ONE+(T(I)-T0)*TC6)
0156      C2C=C2*(ONE+(T(I)-T0)*TC6)
0157      KAPPA=FAKE(1)
0158      TAND=AIM/RA
0159      IF(FC.GT.0.001) GO TO 210

```

Program 2, continued

```

0160          L1=DLOG10(D2(I)/C1C)+DLOG10(C2C/D3(I))
0161          L2=DLOG10(D3(I)/D2(I))
0162          L3=DLOG10(C2C/C1C)
0163          R=ONE-L1*KAPPA*(ONE+TAND**2)/L3
0164          KAPPAC=R*KAPPA/((L3/L2)-TWO*L1*KAPPA/L2+(ONE-R)*L1*KAPPA/L2)
0165          TANDC=TAND/R
0166          RE=KAPPAC
0167          TAM=TANDC-TANW2
0168          AIM=RE*TAM
0169          GO TO 15
0170          210 RE=RA+8368.D-4*(RA**2-RA)*(C2C-D3(I))/C2C
0171          18 TAM=AIM/RE-TANW2*(4.2D-1+W2/RA)/(4.2D-1+W2)
0172          AIM=RE*TAM
0173          15 WRITE(6,300) ANC,DX,THC,FCC,B,RE,AIM,TAM,Z17
0174          SIGMA=1.6669198D-2*AIM/DSQRT(LW02)
0175          WRITE(6,301) T(I),SIGMA,C2C
0176          10 CONTINUE
0177          GO TO 77
0178          88 CALL EXIT
0179          END

```

Output

RAYTHEON POLYIMIDE LAMINATE (OAK) TEMP. RUN 8-3-79

DS	SN	D2	D3	AX	TEMP	I
0.0233	5.4206	0.0	0.9948	2.00000	24.00	1
0.0263	5.3965	0.0	0.9951	2.00000	52.00	2
0.0251	5.3842	0.0	0.9953	2.00000	77.00	3
0.0280	5.3681	0.0	0.9956	2.00000	100.00	4

&CONST

```

DA= .600000000000000012D-02,DXQ= .71999999999999980D-02,
5.9926999999999992 ,DT= 21.0000000000000000 ,
.4000000000000019D-03,A6= .0
.48275999999999993D-03,TC2= .3533000000000000000D-08,
.62090000000000001D-04,TCB= -.58519000000000023D-09,
.194299999999999986D-04,C1= .3745000000000000000 ,
6.1597999999999994 ,QN= 5.9591000000000006
&END

```

```

DQ= 1.2876000000000008 ,FC= 1.9006000000000007 ,LW=
TCW= .4000000000000008D-02,TCQ= .5400000000000005D-06,A5=
AQ= .15000000000000000D-03,AQQ= .0 ,TC1=
T0= .24.0001000000000000 ,TC3= 2.5000000000000000 ,TC7=
TC9= 3.0000000000000000 ,TC0= .999999999999997D-05,TC6=
C2= 1.0027999999999991 ,D= .6650000000000036D-01,AN=

```

NS	DS	D,CORR.	FC	B	K1	K2
----	----	---------	----	---	----	----

6.1596	0.0166	0.0665	1.9025	0.2238	4.2987	0.059233
			TEMP.= 24.0 DEG.C.		SIGMA= 0.2806D-03MHO/CM	
6.1463	0.0196	0.0665	1.8965	0.2286	4.4583	0.072154
			TEMP.= 52.0 DEG.C.		SIGMA= 0.3419D-03MHO/CM	
6.1341	0.0194	0.0665	1.8912	0.2306	4.5282	0.071714
			TEMP.= 77.0 DEG.C.		SIGMA= 0.3397D-03MHO/CM	
6.1229	0.0213	0.0666	1.8863	0.2336	4.6312	0.080035
			TEMP.= 100.0 DEG.C.		SIGMA= 0.3792D-03MHO/CM	

TAN Z4/Z14

0.013779	0.100000D+01	0.166215D-07
SAMPLE HOLDER DIA.= 1.00280		
0.016187	0.999999D+00	-0.248313D-08
SAMPLE HOLDER DIA.= 1.00335		
0.015837	0.100000D+01	0.804382D-09
SAMPLE HOLDER DIA.= 1.00383		
0.017282	0.100000D+01	0.402349D-08
SAMPLE HOLDER DIA.= 1.00428		

Program 3 is the latest version for calculating a temperature run for a sample at the bottom of the sample holder. It includes a correction for the fact that a node shift in the hot zone of hollow waveguide does not result in an equal shift in the cold slotted section because the guide wavelengths are different in the two zones. The changes appear in statements 43-47, and 174 in the following program.

Program 3 Shorted Line Temperature Run

FORTRAN IV G1 RELEASE 2.0

```

0001      INTELER+4 I,J,K,N,NX,KOUNT,COUNT
0002      REAL+8 K3,Y,XE,AN,SN,LW,DX,DS,DA,X,A,B,A2,B2,Z14RE,Z14IM,TWO,
2BOLD,Z14IOD,Z14ROD,ERROR1,EROLD,AOLD,AIM,RE,TAM,Z1RE,Z11IM,WE,
9KAPPA,KAPPAC,L1,L2,L3,R,TAND,TANDC,D2,D,D3,SNC,TC1,T,T0,TC2,TC3,
3COSINE,FC,W,ZM,Y1,TAHA,TANB,PII,PII2,ZRC,ONE,STEP(22)/1.5D-2,
41.2D-2,
41.D-2,7.D-3,5.D-3,2.D-3,1.D-3,5.D-4,2.D-4,1.D-4,5.D-5,2.D-5,
51.D-5,
55.D-6,2.D-6,1.D-6,1.D-7,1.D-8,1.D-9,1.D-10,1.D-11,1.D-12/,NDB,
GF(2)/1.D0,-1.D0/,SOLD,RA,TANW,DC,DDO,DD,TC4,TC5,WC1,WC2,TC6,LW02,
7WL2,DDA,A5,A6,C1,C2,C1C,C2C,FCC,SIGMA,AX,TCB
0003      COMPLEX+16 Z1,Z2,Z3,Z9,Z10,Z11,Z12,Z13,Z14R,Z14I,Z16,K3C,
2Z14,Z12NEW,Z12RE,Z12IM,Z12SQ,G,H,Z15,Z2A,ZONE,ZOONE
0004      REAL+8 SILLY(2),FAKE(2)
0005      EQUIVALENCE (SILLY(1),Z11),(FAKE(1),Z15)
0006      DIMENSION DS(30),SN(30),D(30),D2(30),D3(30),N(30),DATE(39),
2T(30),DD(30),AX(30),SIGMA(30),C2C(30)
0007      NAMELIST/IN/DS,SN,N,NX,D,D2,D3,T,DD,AX/CONST/DA,AN,FC,LW,TANW,
2TC2,TC3,T0,DDO,TC4,TC5,A5,A6,C1,C2,TC6,TC1,TCB
0008      200 FORMAT(1X,39A2)
0009      201 FORMAT(1H0,20X,39A2)
0010      220 FORMAT(1J,5X,2HDS,8X,2HSN,6X,1HD,7X,2HD2,7X,2HD3,6X,1HN,
2UX,2HDD,4X,11HTEMP,DEG.C.)
0011      230 FORMAT(2X,F8.4,1X,F8.4,2X,F7.4,2X,F6.4,2X,F8.5,2X,I2,2X,F8.4,
22X,F8.2)
0012      100 FORMAT(1H0,5X,2HNS,6X,2HDS,4X,7HD,CORR.,4X,2HFC,6X,1HB,6X,2HK1,
29X,2HK2,9X,3HTAN,15X,7HZ11/(14//)
0013      300 FORMAT(2X,F7.4,2X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4,3X,F9.6,
23X,F9.6,3X,E13.6,2X,E13.6)
0014      301 FORMAT(2L,8HDEG.C. 4X,8HSIGMA IN,1X,6HMHD/CM,1X,
220HSA/MPL E HOLDER DIA.'')
0015      302 FORMAT(10X,F7.1,4X,E11.4,10X,F8.5)
0016      77 READ(5,200) END=Q8) DATE
0017      WRITE(6,201) DATE
0018      READ(5,INI)
0019      READ(5,CONST)
0020      WRITE(6,220)
0021      WRITE(6,230)(DS(I),SN(I),D(I),D2(I),D3(I),N(I),DD(I),T(I),I=1,NX)
0022      WRITE(6,CONST)
0023      WRITE(6,100)
0024      ZONE=(1.00,0.00)
0025      ZOONE=(0.00,1.00)
0026      ONE=1.00
0027      TWO=2.00
0028      PII=3.1415926536D0
0029      PII2=PII*TWO
0030      ZRO=0.00
0031      DO 10 I=1,NX
0032      IF(DD(I).EQ.DDO) GO TO 22
0033      DC=D(I)+(DD0-DD(I))*2.54D0+TC4*(T(I)-T0)+TC5*(T(I)-T0)**2
0034      GO TO 23
0035      22 DC=D(I)*(ONE+(T(I)-T0)*TCD)
0036      23 SNC=SN(I)+(TC1*(T(I)-T0)+TC2*(T(I)-T0)**TC3)

```

Program 3, continued

```

0037      W=ONE+FC
0038      LW02=LW**2/W
0039      IF(FC.GT.0.D0) GO TO 33
0040      WL2=LW
0041      WC2=1.D30
0042      GO TO 35
0043      33 WC1=3.412586D0*1.27D0*C2
0044      WC2=WC1*(ONE+TC6*(T(I)-T0))
0045      WL2=DSQRT(LW02*WC2**2/(WC2**2-LW02))
0046      35 K3=WL2/(PI12*DC)
0047      Y=PII2*((SNC-AN)/LW-DC/WL2)
0048      DDA=DA-(ONE+A5*(T(I)-T0)+A6*(T(I)-T0)**2)
0049      DX=DS(I)-DDA
0050      IF(DX.LE.ZRO) GO TO 10
0051      CUSINE=DCOS(PII*DX/LW)**2
0052      X=DSIN(PII*DX/LW)/DSQRT(AX(I)-COSINE)
0053      Y1=DTAN(Y)
0054      Z1=ZONE*Y1
0055      Z2A=ZONE*X
0056      Z2=Z2A-Z1
0057      Z3=ZONE-Z2A*Z1
0058      Z9=Z2/Z3
0059      Z10=ZONE*(-K3)
0060      Z11=Z10*Z9
0061      Z11RE=SILLY(1)
0062      Z11IM=SILLY(2)
0063      ZM=DSORT(Z11RE**2+Z11IM**2)
0064      IF(N(I).EQ.1) GO TO 141
0065      IF(N(I).GE.2) GO TO 142
0066      141 IF(ZM.LE.ONE.AND.Z11RE.GE.ZRO) GO TO 150
0067      IF(ZM.LE.ONE.AND.Z11RE.LT.ZRO) GO TO 151
0068      IF(ZM.GT.ONE.AND.Z11RE.GE.ZRO) GO TO 152
0069      IF(ZM.GT.ONE.AND.Z11RE.LT.ZRO) GO TO 153
0070      142 IF(ZM.LE.ONE.AND.Z11RE.GE.ZRO) GO TO 170
0071      IF(ZM.LE.ONE.AND.Z11RE.LT.ZRO) GO TO 171
0072      IF(ZM.GT.ONE.AND.Z11RE.GE.ZRO) GO TO 172
0073      IF(ZM.GT.ONE.AND.Z11RE.LT.ZRO) GO TO 173
0074      150 B=ONE
0075      A=42.D-1*DX/LW
0076      GO TO 160
0077      151 B=22.D-1
0078      A=2.D0*DX/LW
0079      GO TO 160
0080      152 B=ONE
0081      A=6.D0*DX/LW
0082      GO TO 160
0083      153 B=18.D-1
0084      A=DX/LW
0085      GO TO 160
0086      170 NDB=N(I)
0087      B=(NDB-ONE)*PII+7854.D-4
0088      A=4.D0*DX/LW
0089      GO TO 160
0090      171 NDB=N(I)
0091      B=NDB*PII-7854.D-4
0092      A=4.D0*DX/LW
0093      GO TO 160
0094      172 NDB=N(I)
0095      B=(2.D0*NDB-1.D0)*15708.D-4-2.D-1/NDB
0096      A=DX/LW
0097      GO TO 160
0098      173 NDB=N(I)
0099      B=(2.D0+NDB-1.D0)*15708.D-4+2.D-1/NDB
0100      A=DX/LW
0101      160 TAHB=DTANH(A)
0102      TANB=DTAN(B)
0103      A2=TAHB*(ONE+TANB**2)/(ONE+TAHB**2*TANB**2)
0104      B2=TANB*(ONE-TAHB**2)/(ONE+TAHB**2*TANB**2)
0105      Z14RE=(A*A2+B*B2)/(A**2+B**2)
0106      Z14IM=(A*B2-B*A2)/(A**2+B**2)

```

Program 3, continued

```

0107      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
0108      COUNT=0
0109      440 COUNT=COUNT+1
0110      DO 400 K=1,22
0111      SOLD=STEP(K)
0112      TAHA=DTANH(A)
0113      DO 600 J=1,2
0114      420 WE=ONE+STEP(K)*F(J)
0115      KOUNT=0
0116      401 KOUNT=KOUNT+1
0117      IF(KOUNT.GT.10.AND.STEP(K).LE.1.D-3) GO TO 411
0118      GO TO 425
0119      411 STEP(K)=STEP(K)*10.D0
0120      GO TO 420
0121      425 BOLD=B
0122      Z14IOD=Z14IM
0123      Z14ROD=Z14RE
0124      EROLD=ERROR1
0125      B=B*WE
0126      TANB=DTAN(B)
0127      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
0128      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
0129      Z14RE=(A*A2+B*B2)/(A**2+B**2)
0130      Z14IM=(A*B2-B*A2)/(A**2+B**2)
0131      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
0132      IF(ERROR1.LE.EROLD) GO TO 401
0133      Z14IM=Z14IOD
0134      Z14RE=Z14ROD
0135      B=BOLD
0136      ERROR1=EROLD
0137      STEP(K)=SOLD
0138      600 CONTINUE
0139      TANB=DTAN(B)
0140      DO 700 J=1,2
0141      421 WE=ONE+STEP(K)*F(J)
0142      KOUNT=0
0143      402 KOUNT=KOUNT+1
0144      IF(KOUNT.GT.10.AND.STEP(K).LE.1.D-3) GO TO 412
0145      GO TO 428
0146      412 STEP(K)=STEP(K)*10.D0
0147      GO TO 421
0148      428 AOLD=A
0149      Z14ROD=Z14RE
0150      Z14IOD=Z14IM
0151      EROLD=ERROR1
0152      A=A*WE
0153      TAHA=DTANH(A)
0154      A2=TAHA*(ONE+TANB**2)/(ONE+TAHA**2*TANB**2)
0155      B2=TANB*(ONE-TAHA**2)/(ONE+TAHA**2*TANB**2)
0156      Z14RE=(A*A2+B*B2)/(A**2+B**2)
0157      Z14IM=(A*B2-B*A2)/(A**2+B**2)
0158      ERROR1=DSQRT((Z14RE-Z11RE)**2+(Z14IM-Z11IM)**2)
0159      IF(ERROR1.LE.EROLD) GO TO 402
0160      Z14RE=Z14ROD
0161      Z14IM=Z14IOD
0162      A=AOLD
0163      ERROR1=EROLD
0164      STEP(K)=SOLD
0165      700 CONTINUE
0166      IF(ERROR1.LE.1.D-7) GO TO 450
0167      400 CONTINUE
0168      IF(ERROR1.GT.1.D-7.AND.COUNT.LE.2) GO TO 440
0169      450 Z12RE=ZONE*A
0170      Z12IM=ZONE*B
0171      Z12NEW=(Z12RE+Z12IM)**2
0172      K3C=K3*ZONE
0173      Z13=-Z12NEW*K3C**2
0174      FCC=WL2**2/WC2**2
0175      W=ONE+FCC
0176      G=ZONE*FCC

```

Program 3, continued

```

0177      H=ZONE+W
0178      Z15=(G+Z13)/H
0179      Z14R=ZONE*Z14RE
0180      Z14I=ZONE*Z14IM
0181      Z14=Z14R+Z14I
0182      Z16=Z11/Z14
0183      RA=FAKE(1)
0184      AIM=-FAKE(2)
0185      C1C=C1*(ONE+(T(I)-T0)*TC6)
0186      C2C(I)=C2*(ONE+(T(I)-T0)*TC6)
0187      KAPPA=FAKE(1)
0188      TAND=AIM/RA
0189      IF(FC.GT.0.00) GO TO 210
0190      L1=DLOG10(D2(I)/C1C)+DLOG10(C2C(I)/D3(I))
0191      L2=DLOG10(D3(I)/D2(I))
0192      L3=DLOG10(C2C(I)/C1C)
0193      R=ONE+L1*KAPPA*(ONE+TAND**2)/L3
0194      KAPPAC=R*KAPPA/((L3/L2)-TWO*L1*KAPPA/L2+(ONE-R)*L1*KAPPA/L2)
0195      TANDC=TAND/R

0196      RE=KAPPAC
0197      TAM=TANDC-TANW*DDA/DA
0198      AIM=RE*TAM
0199      GO TO 15
0200      210 RE=RA+8368.D-4*(RA**2-RA)*(C2C(I)-D3(I))/C2C(I)
0201      18 TAM=AIM/RE-TANW*DDA*(4.2D-1+W/RA)/(4.2D-1+W)*DA
0202      AIM=RE*TAM
0203      15 WRITE(6,300) SNC,DX,DC,FCC,B,RE,AIM,TAM,Z16
0204      SIGMA(I)=1.6669198D-2*AIM/DSQRT(LW02)
0205      10 CONTINUE
0206      WRITE(6,301)
0207      DO 11 I=1,NX
0208      WRITE(6,302) T(I),SIGMA(I),C2C(I)
0209      11 CONTINUE
0210      GO TO 77
0211      88 CALL EXIT
0212      END

```

In the latter part of this report period we have investigated the possibility of using derivatives in the shorted line (also corresponding relations in the open circuited line) calculations for finding a and b in the expression

$$\tanh(a + jb) / (a + jb) = C + jd$$

when C and D are known. In principle the use of derivatives to extrapolate to the solution could provide faster, more efficient programs than the blind stepping method we have used. In practice we found that the damping required (in a general use program) because of large changes in values of the derivatives resulted in little or no improvement.

If approximately correct initial values of a and b are obtained from charts (or in the case of thin samples at the quarter wave plane, from algebraic expressions) iteration using derivatives is useful, as in our programs for the HP9810A calculator. These are available on request.

DATA INDEX

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DIELECTRIC PARAMETERS

Dielectric parameters in this series of reports have the variables in one of the following notations:

- ϵ' , ϵ'/ϵ_0 , K, K1, dielectric constant relative to vacuum
- ϵ'' , ϵ''/ϵ_0 , K2, dielectric loss factor relative to vacuum
- $\tan \delta$, $\tan \delta_d$, TAN DELTA, D.F., dielectric loss tangent (dissipation-factor)
- μ_m^1 , μ'/μ_0 , magnetic permeability relative to vacuum
- μ_m'' , μ''/μ_0 , magnetic loss factor relative to vacuum
- $\tan \delta_m$, magnetic loss tangent
- σ , a.c. volume conductivity in mho/cm
- ρ , a.c. volume resistivity in ohm-cm

MATERIALS INDEX

I. Inorganic Compounds

Aluminum nitrides General Electric/RSD Measurements made under AMMRC contract DAAC46-79-C-0096, reference AMMRC report AMMRC-TR81-45(March 1982)

CVD-AlN-3 24 GHz, E parallel to deposition plane Hot-pressed (HP-21) 2.64 gm/cc(81%)

T°C	K	tan δ	T°C	K	tan δ
30	7.47	.0020	27.5	5.963	.00216
96	7.56	.0019	136	6.038	.00243
205	7.68	.0026	222	6.090	.00275
300	7.83	.0122	311	6.144	.00239
401	7.98	.0225	408	6.202	.00234
518	8.21	.0606	507	6.285	.00276
589	8.36	.110	607	6.380	.00320
672	8.59	.181	708	6.457	.00372
723	8.74	.248	738	6.492	.00395
800	9.0	.35	800	6.549	.00435

Aluminum oxide

Single crystal, sapphire

Unknown

E ⊥ to optic axis, 8.5 GHz

	K	tan δ
Sample 1	9.42	.00006 ± .00004
2	9.38	<.00002

Ceramic, Wesgo 4078

Western Gold & Pt.

8.5 GHz, 24°C

	K	tan δ
	9.31	.00034

Aluminum oxynitride crystal

AMMRC

T°C	Freq., Hz	10 ²	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷
25	K'	8.56	8.56	8.56	8.56	8.56	8.56
	tan δ	.0015	.0011	.0006	.0005	.0005	.0004
	σ	7.1E-13					
150	K'	8.62	8.60	8.60	8.60	8.60	8.60
	tan δ	.0033	.0037	.0024	.0018	.0010	.0006
	σ	1.6E-12					
300	K'	8.97	8.79	8.72	8.65	8.64	8.64
	tan δ	.0270	.0108	.0044	.0029	.0026	.0021
	σ	1.343E-11					
400	K'	10.0	9.40	9.13	8.95	8.76	8.72
	tan δ	.0709	.0495	.0229	.0078	.0037	.0031
	σ	3.94E-11					
500	K'	14.0	11.7	9.92	9.18	8.95	8.87
	tan δ	1.014	.212	.0941	.0370	.0136	.0070
	σ	7.89E-10	1.38E-9				

Beryllium oxide

Ceramics

418S	Ceradyne	K150	Unknown
23°C, 8.5 GHz Density = 2.842 g/cm ³		23°C, 8.5 GHz	
$\kappa' = 6.60$; $\tan \delta = .00030$		Sample	Density (g/cm ³)
		1	2.891
		2	2.882
			κ
			.6.715
			.00037
			.6.688
			.00039

Boron nitride

Cubic, CVD Specimen No. 1025(3)

24°C, 24 GHz

$\kappa' = 7.01$; $\tan \delta = .0048$

Hot-pressed, 8.5 GHz, 24°C

General Electric/RSD measured under
AMMRC Contract No. DAAG46-79-C-0047;
reference AMMRC TR79-45 (August, 1979)

Grade HP			Carborundum			Grade HBC			Union Carbide		
Sample	Density (g/cm ³)	κ	$\tan \delta$	Sample	Density (g/cm ³)	κ	$\tan \delta$	Sample	Density (g/cm ³)	κ	$\tan \delta$
1	1.895	4.28	.00078	1	1.943	4.10	.00015				
2	1.879	4.27	.00078	2	1.944	4.08	.00013				

Woven fiber

BN-3DX 59-1-1.74

24°C

14 GHz

Ford Aerospace

Face 1, rotation 0°

Face Rotation, °	κ	$\tan \delta$	T°C	κ	$\tan \delta$
1	0	.3.775	.00111	200	.3.796
	90	.3.683	.00047		
2	0	.3.706	.00066	400	.3.797
	90	.3.720	.00148		
			600	.3.805	.00092
			800	.3.818	.00135

Cordierite ceramics

Brunswick 2, 8.5 GHz

Against short

Brunswick

Sample	Face	κ	$\tan \delta$	κ	$\tan \delta$	Density (g/cm ³)
1	1	4.735	.00050	4.69	.00047	2.4472
	2	4.729	.00047			
2	1	4.730	.00050	4.69	.00047	2.5521
	2	4.722	.00047			
3	1	4.717	.00051			2.4372
	2	4.711	.00056			

Cordierite ceramics (cont.)

Brunswick 2 (1+2+3) stacked
Silver paint + silver foil

Brunswick 2-2

Resonant-cavity method TE114

T°C	K	tan δ
25	4.7237	.00050
81	4.7410	.00054
103	4.7484	.00054
133.5	4.7585	.00057
162	4.7664	.00058
200	4.781	.00066
232	4.7936	.00081
261	4.806	.00114
372	4.8464	.0023
409	4.8606	.0033
418	4.865	.0035
457	4.886	.0046
500	4.937	.0061

Standing-wave method

T°C	K	tan δ
23	4.729	.00052
100	4.754	.00054
200	4.790	.00062
300	4.829	.00137
400	4.863	.00283
500	4.890	.00570
600	4.935	.0115
700	4.980	.0228
900	5.09	.080

$\frac{\Delta K/K}{\Delta T}$ at 300°C = $\frac{4.8205 - 4.7237}{4.7237 \times 275}$ = 7.45E-5;

$\frac{\Delta K/K}{\Delta T}$ at 900°C = 8.70E-5

Coor CD1

Coors

Against short

$\lambda/4$ away

Sample	Face	K	tan δ	K	tan δ	Density (g/cm³)
1	1	4.858	.00133	4.857	.00122	2.4709
	2	4.859	.00129	4.856	.00120	
2	1	4.885	.00122	4.872	.00120	2.4816
	2	4.881	.00122	4.871	.00121	
3	1	4.894	.00134	4.884	.00121	2.4862
	2	4.894	.00124	4.883	.00120	

Coor CD1-1, silver paint + silver foil

Resonant-cavity method

T°C	K	tan δ
26.3	4.8593	.00130
88	4.8772	.00145
119	4.888	.00157
131	4.891	.00164
166.7	4.905	.0018
210.5	4.919	.00229
243	4.928	.00243
265	4.935	.0025
287	4.941	.0035
308	4.955	.0039
327	4.962	.0045
346	4.971	.0050
373	4.983	.0072

Standing-wave method

T°C	K	tan δ
23	4.857	.00130
100	4.881	.00146
200	4.913	.00200
300	4.943	.00307
400	4.975	.00538
500	5.009	.0111
600	5.046	.0189
700	5.092	.034
800	5.142	.060
900	5.202	.110

$\frac{\Delta K/K}{\Delta T}$ at 300°C = $\frac{.0917}{4.859 \times 273.7}$ = 6.89E-5;

$\frac{\Delta K/K}{\Delta T}$ at 900°C = $\frac{.345}{4.857 \times 877}$ = 8.10E-5

Cordierite ceramics (cont.)

"Rayceram" QNP 2102

Raytheon

Resonant-cavity method

4.17 GHz (TE111 mode)			8.73 GHz (TE113 mode)		
T°C	K	tan δ	T°C	K	tan δ
20.5	4.7448	.0018	20.5	4.7439	.00165
64	4.7600	.0019	74.7	4.7633	.0019
104.5	4.7767	.0022	100.5	4.7761	.0020
255.3	4.837	.0034	254	4.8335	.0034
334	4.869	-	295	4.8492	.0041
368	4.880	-	374	4.9018	.0052
			414	4.9145	.0057

Standing-wave method

"Rayceram" QNP 2102 in room-temperature holder

At 8.515 GHz

	K	T°C	K	tan δ
Pc. 1	4.734	23	4.736	.00154
Pc. 2	4.701	100	4.769	.0020
Pc. 3	4.714	200	4.809	.0033
Pcs. 1/2/3	4.736	300	4.852	.0047
		400	4.897	.0063
		500	4.944	.0082
		600	4.992	.0102
		700	5.040	.0124
		800	5.096	.0152

Cordierite + 10% TiO₂

Raytheon

8.515 GHz, standing-wave method

T°C	Face	K	tan δ
24	RTH	1	6.277
24		2	6.272
28	HTH	2	6.252
100		6.252	.0017
200		6.280	.0026
300		6.292	.0041
400		6.314	.0058
500		6.353	.0077
600		6.391	.0101
700		6.425	.0134
800		6.443	.0153

Ferrites							Transtech
TT-1-105			2.45 GHz				
T°C	ϵ' / ϵ_0	$\tan \delta$	Conductivity (mho-cm)	μ' / μ_0	$\tan \delta_m$	Attenuation (db/cm)	
25	12.8	.0008±.0005	1.4E-5	.160	-10.03	13.6	
50	12.8	.001	1.7E-5	.141	-8.60	11.4	
75	12.8	.0012	2.E-5	.081	-11.0	9.36	
100	12.8	.0015	2.6E-5	.023	23.8	6.47	
125	12.9	.0015	2.6E-5	.162	1.34	2.64	
150	12.9	.0011	1.8E-5	.48	.035	.160	
175	13.0	.0015	2.65E-5	.80	.0086	.0623	
200	13.1	.0025	4.46E-5	1.053	.0062	.073	
250	13.3	.0067	1.21E-4	1.036	.0072	.117	
300	13.4	.0139	2.53E-4	1.031	.0080	.184	
350	13.6	.0314	5.81E-4	1.019	.0094	.344	
400	13.8	.070	1.31E-3	1.014	.0124	.707	
500	14.1	.392	7.5E-3	1.00	.028	3.71	
1 GHz							
25	12.8	.0005±.0003	3.6E-6	2.097	2.097	7.7	
 "Ferrimag" 5 ($BaO-6F_2O_3$)							Permag
24°C, 14 GHz							
$\kappa' = 20.5$, $\tan \delta_d = .009±4$, $\mu' / \mu_0 = 1.37±1$, $\tan \delta_m = .024±.01$							
 Germanium mullite							General Electric
24 GHz							
T°C	κ	$\tan \delta$		T°C	κ	$\tan \delta$	
25	6.92	.0003		450	7.54	.0071	
77	7.00	.0002		540	7.67	.0128	
100	7.03	.0003		606	7.76	.0152	
180	7.16	.0011		674	7.85	.0180	
300	7.33	.0031		734	7.93	.022	
375	7.44	.0048		800	8.04	.026	
 Lithium Niobate							MIT Lincoln Lab.
24 GHz							
$E \parallel Y$							
κ 27.9							
$\tan \delta$.0122							
$E \parallel X$							
39.							
.0054							
 Magnesium fluoride, ITRTRAN 1							Eastman Kodak
8.5 GHz 23°C							
$\kappa = 5.276$ $\tan \delta = .00017$							

Magnesium fluoride, IRTRAN 1 (cont.)

Eastman

24 GHz

T°C	κ	$\tan \delta$	T°C	κ	$\tan \delta$
25.3	5.29	.0001	367	5.78	.0006
53	5.33	.0001	451	5.93	.0007
104	5.39	.0001	517	6.06	.0009
146	5.45	.0002	597	6.23	.0013
194	5.52	.00025	654	6.36	.0022
239	5.57	.00035	722	6.6	.060
293	5.66	.0005			

Sialons and Silicon nitride

AFML (Ruh)

 $\text{Si}_3\text{N}_4 + 6\% \text{CeO}_2 + 15\% \text{BN}$ 1800°C vacuum hot-pressed,
20 Dec. 1977, density=2.866 g/cm³1900°C vacuum hot-pressed, Jan. 1978,
density=2.848 g/cm³

14 GHz

Face	Rotation (degrees)	T°C	κ	$\tan \delta$	Face	Rotation (degrees)	T°C	κ	$\tan \delta$
1	0	22	7.175	.00966	1	0	22	7.166	.0131
	90	22	7.157	.00931		90	22	7.131	.0138
2	0	22	7.159	.00935	2	0	22	7.144	.0133
	90	22	7.148	.00875		90	22	7.173	.0134
1	0	100	7.25	.0125	1	0	100	7.22	.0154
		200	7.35	.0180			200	7.32	.0210
		300	7.45	.0247			300	7.42	.0249
		400	7.58	.0357			400	7.53	.0415
		500	7.72	.0475			500	7.65	.0548
		600	7.88	.059			600	7.78	.070

G.E. 128-2

General Electric

Resonant-cavity measurements
at approx. 8.5 GHz

Standing-wave measurements at 24 GHz

T°C	κ	$\tan \delta$	T°C	κ	$\tan \delta$
25	7.67	.0014	25	7.65	.0028
100	7.72	.0014	100	7.67	.0022
200	7.78	.0015	200	7.69	.0024
300	7.85	.0015	300	7.73	.0023
400	7.91	.0015	400	7.78	.0026
500	7.97	.0015	500	7.84	.0027
600	8.05	.0015	600	7.89	.0027
700	8.13	.0016	700	7.95	.0026
800	8.21	.0017	800	8.02	.0025
900	8.30	.0018	25	7.76	.0019
1000	8.40	.0021			
1100	8.51	.0026			
1150	8.57	.0030			
1200	8.62	.0037			
1220	8.65	.0040			
1250	8.70	.0050	-23-		
1270	8.75	.0098			

Sialons and Silicon nitride (cont.)

G.E. 129-1

Resonant-cavity measurements
at approx. 8.5 GHz

General Electric

Standing-wave measurements at 24 GHz

T°C	K	tan δ	T°C	K	tan δ
25	7.79	.0015	25	7.67	.0016
100	7.815	.0016	100	7.68	.0022
200	7.86	.0017	200	7.70	.0028
300	7.91	.0017	300	7.73	.0031
400	7.97	.0018	400	7.77	.0031
500	8.03	.0019	500	7.82	.0032
600	8.09	.0020	600	7.87	.0033
700	8.16	.0021	700	7.94	.0035
800	8.22	.0022	800	8.01	.0040
900	8.30	.0023			
1000	8.37	.0026			
1100	8.46	.0030			
1150	8.50	.0033			
1200	8.57	.0038			
1260	8.67	.014			

G.E. 130-1

T°C	K	tan δ	T°C	K	tan δ
25	7.44	.0014	25	7.55	.00182
100	7.48	.0014	100	7.58	.00225
200	7.53	.0015	200	7.62	.00266
300	7.58	.0015	300	7.65	.00274
400	7.62	.0016	400	7.69	.00272
500	7.66	.0017	500	7.72	.00268
600	7.71	.0018	600	7.77	.00276
700	7.75	.0019	700	7.81	.00292
800	7.81	.0020	800	7.87	.0031
900	7.87	.0022			
1000	7.93	.0025			
1100	8.02	.0040			
1150	8.08	.0057			
1200	8.18	.0100			

Silica

Corning 7940 (1979), 8.5 GHz

Corning

In room-temperature sample holder

Samples	K	tan δ
1 pc.	3.825	.00012 + .00003
2 pcs. stacked	3.816	.00010 + .00002
3 pcs. "	3.815	.00010 + .00003
4 pcs. "	3.820	.000122 + .000012

Silica (cont.)

Corning 7940 (cont.)

Corning

Temperature run, 2 pcs. stacked

T°C	K	tan δ
22	3.815	.0001 + .0001 - .00005
104	3.819	
165	3.823	
222	3.829	
326	3.837	
410	3.843	
510	3.853	
611	3.862	
699	3.879	
751	3.882	

Temperature run, 3 pcs. stacked

T°C	K	tan δ
19.6	3.812*	.00014 + .00005
100	3.816	.00012
207	3.822	.00010
300	3.829	.00011
422	3.829	.00010
488	3.847	.00011
572	3.847	.00011
656	3.862	.00011
722	3.879	.00010
750	3.882	.00013

* Not corrected for stacking error.

Temperature run, 4 pcs. stacked

T°C	K**	tan δ
25.3	3.822	.00014 + .0003
100	3.827	.00011
200	3.835	.00010
297	3.844	.00010
400	3.855	.00010
493	3.866	.00012
600	3.878	.00013
725	3.894	.00014
760	3.900	.00014
800	3.905	.00014
25.0	3.823	.00014

Previous resonant-cavity data[†]

T°C	K	tan δ
25	3.823	.00015 + .00007
100	3.829	.00014
200	3.836	.00012
300	3.845	.00012
400	3.855	.00012
500	3.866	.00012
600	3.878	.00012
700	3.890	.00012
800	3.904	.00013

** Corrected for stacking error.

† Corrected for thermal expansion and frequency shift from 4 to 8.5 GHz.

Slip cast with moisture proofing, 8.5 GHz

Harbison-Walker

T°C	K	tan δ
22	3.224	.00075
100	3.233	.00095
200	3.242	.00092
300	3.247	.00090
400	3.257	.00140
500	3.268	.00180

T°C	K	tan δ
600	3.281	.00250
700	3.293	.00335
800	3.304	.0042
900	3.317	.0050
22	3.198	.00054

Silica (cont.)

Slip cast, Brunswick 201B (1978), 8.5 GHz

Brunswick

T°C	κ	$\tan \delta$	T°C	κ	$\tan \delta$
22	3.460	.00104	650	3.481	.00042
100	3.471	.00080	700	3.480	.00049
200	3.475	.00050	750	3.479	.00058
300	3.475	.00035	800	3.482	.00068
400	3.474	.00028	900	3.490	.00090
500	3.477	.00030	171	3.456	.00016
600	3.481	.00037	57	3.450	.00024

Silica Composite ADL-4D6 (1.59gm/cc)

General Electric/RSD measured under
AMMRC Contract No. DAAG46-79-C-0047;
reference AMMRC TR79-45 (August, 1979)

After preheat to 700°C

8.5 GHz, Mode 1			---continued			24 GHz As received		
T°C	K	tan δ	T°C	K	tan δ	T°C	K	tan δ
22	2.656	.00153	503	2.673	.00062	24	2.878	.0072
1 hour				587	2.684	.00092	117	2.878 .0055
22	2.660	.00218	735	2.703	.00120	217	2.856 .0039	
67.5	2.658	.00202	790	2.709	.00132	271	2.841 .0023	
83.5	2.657	.00185	835	2.714	.0016	320	2.833 .0016	
116.6	2.655	.00093	973	2.726	.0028	404	2.823 .0018	
123	2.654	.00083	1100	2.736	.0032	496	2.813 .0020	
190	2.650	.00079	1178	2.741	.0036	546	2.809 .0021	
252	2.649	.00061	1234	2.746	.0040	698	2.797 .0022	
300	2.652	.00061	1290	2.77	.0045	750	2.793 .0023	
411	2.663	.00120	1321	2.79	.0048	800	2.790 .0023	
429	2.665	.00086	1400	2.82	.0057	95	2.822 .0020	

8.5 GHz, Mode 2

22	2.8295	.00196	623	2.832	.00079
130	2.8284	.00122	731	2.835	.00126
189	2.826	.00086	1016	2.860	.00302

Silicates

Corning 9754 glass

Corning

8.515 GHz

24 GHz

T°C	κ	$\tan \delta$	T°C	κ	$\tan \delta$
22	8.72	.0069	23	8.69	.0089
100	8.91	.0069		8.83	.0090
200	9.18	.0070		9.05	.0093
300	9.47	.0072		9.29	.0097
400	9.78	.0074		9.55	.0103
500	10.08	.0079		9.83	.0108
600	10.4	.0085		10.14	.0116

Silicates (cont.)

"Cervit" Glass-1, 8.515 GHz

Owens-Illinois

T°C	κ	$\tan \delta$	T°C	κ	$\tan \delta$
22	6.38	.050	400	8.52	.145
100	6.87	.066	444	8.88	.184
200	7.37	.081	538	9.12	.346
300	7.85	.097			

Silicon carbide

Vesuvius Crucible

Four-terminal measurements on samples
of various conductivities

Sample designation	Resistivity in ohm-cm		
	100 Hz	1 kHz	10 kHz
NR2	.661	.660	.658
NH1	.06414	.06385	.06377
LRL	.004593	.004592	.004509
LH1	.003604	.003598	.003587

Silicon carbide + glass matrix

ITT Gilfillan

May stone .25, 2.45 GHz

T°C	κ	$\tan \delta$	T°C	κ	$\tan \delta$
25	25.6	.247	300	29.5	.0983
100	26.2	.275	400	29.7	.108
150	27.2	.239	450	29.6	.109
200	28.7	.115	500	29.4	.127
250	29.4	.0956			

Repeat run

25	25.6	.190	250	29.3	.0955
100	26.2	.154	300	29.7	.0984
200	28.7	.101	400	29.8	.107

Silicon nitride

Samples from AMMRC

sintered, 8.515 GHz

Sample	Face	Rotation (degrees)	T°C	κ	$\tan \delta$
HP-X-214	1	0	25	8.653	.00744
		90		8.646	.00735
	2	0	8.586	.00655	
		90		8.590	.00654
7-24	1	0	7.787	.0229	
		90		7.742	.0214
	2	0	7.455	.0226	
		90		7.511	.0262
8-3A	1	0	7.840	.467	
		90		7.828	.440

Silicon nitride (cont.)

Hot-pressed, sample HP-X-214, 8.515 GHz

AMMRC

T°C	K	tan δ	T°C	K	tan δ
23.5	8.63	.0064	493	9.17	.0067
100	8.70	.0066	596	9.30	.0065
207	8.81	.0065	679	9.40	.0064
290	8.92	.0065	700	9.44	.0066
395	9.06	.0070	752	9.50	.0067

Ceralloy 147Y-1, 24 GHz

Ceradyne

Measurements in room-temperature sample holder

Sample	Face	Rotation (degrees)	K	tan δ
A	1	0	8.79	.00363
	2	0	8.73	.00894
	2	45	8.83	.00354
	2	135	8.72	.00746
B	1	0	8.26	.00166
	1	45	8.27	.00452
	1	135	8.42	.00385
	2	0	8.25	.0015
	2	90	8.39	.0093

Temperature runs

A, Face 1, 0°

T°C	K	tan δ
25	8.79	.0036
100	8.84	.0041
200	8.90	.0047
300	8.97	.0056
400	9.05	.0061
500	9.14	.0063
600	9.23	.0061
700	9.33	.0062
750	9.38	.0075
800	9.44	.0091

B, Face 1, 0°

T°C	K	tan δ
25	8.26	.0016
100	8.30	.0017
200	8.38	.0019
300	8.47	.0023
400	8.56	.0024
500	8.66	.0023
600	8.77	.0031
700	8.88	.0048
750	8.93	.0057
800	8.99	.0067

Silicon nitride

Chemical vapor deposition, specimen No. 231 General Electric/RSD
Measured at 24GHz under AMMRC Contract No. DAAG46-79-C-0096; reference
AMMRC TR-81-45(March 1982) 24 GHz

T°C	K	tan δ	T°C	K	tan δ
28.5	8.07	.0003	495	8.64	.0004
99	8.13	<.0003	460	8.73	.0004
208	8.24		624	8.82	.0004
294	8.34		650	8.87	.0004
358	8.44		696	8.95	.0005
414	8.53	<.0004	733	6.01	.0005

Silicon nitride plus BN fibers

AVCO

Sample 1 at room temperature

Against short $\kappa' = 9.40$; $\tan \delta = .118$

$$\lambda/4 \text{ away} \quad \kappa' = 9.00; \tan \delta = .144$$

Temperature run, average

T°C	K	$\tan \delta$	T°C	K	$\tan \delta$
25	9.15	.131	500	9.33	.137
100	9.18	.132	600	9.38	.137
200	9.21	.135	700	9.53	.138
300	9.25	.136	800	9.47	.139
400	9.30	.137			

Sample 2 at room temperature

Against short $\kappa' = 9.25$; $\tan \delta = .125$

$$\lambda/4 \text{ away} \quad \kappa^1 = 8.69; \tan \delta = .144$$

Calculated as a magnetic sample:

$$\kappa' = 8.04; \tan \delta_d = .9215; \mu'/\mu_o = 1.12; \tan \delta_m = .121$$

Silicon mullite, ceramic

General Electric

8.5 GHz, density = 3.15 g/cm³

24 GHz, 3.12 g/cm³

T°C	κ	$\tan \delta$	T°C	κ	$\tan \delta$
23	7.02	.0004	23.5	6.98	.0002 \pm .0001
83	7.09	.0005	111	7.04	.0003
207	7.21	.0008	2.3	7.14	.0004
357	7.40	.0023	276	7.22	.0012
440	7.55	.0043	374	7.34	.0032
534	7.60	.0062	460	7.46	.0070
573	7.75	.0067	554	7.59	.0138
632	7.84	.0072	607	7.66	.0177
698	7.95	.0073	660	7.73	.023
740	8.01	.0073	719	7.82	.030
800	8.12	.0072	740	7.86	.033

Sulfur

Merck Chemical

8.5 GHz

	T°C	Density (g/cm³)	κ	$\tan \delta$
Pressed pellet	23	1.683	3.28	.00005±.00001
Fast cooled from liquid	23	1.976	3.78	.00005±.00001
Pressed pellet (m.p. 120°C)	23		3.379	.000046
	48		3.378	.000062
	65		3.378	.000052
	88		3.379	.000008
	101		3.375	.00012
	126.7		3.289	.00038
Liquid (b.p. 447°C)	125		3.38	.0004
	140		3.38	.0007
	160		3.38	.0005
	180		3.39	.0006
	200		3.40	.0006
	220		3.40	.0007
	240		3.40	<.002
	260		3.41	
	280		3.41	
	300		3.38	<.004
	320		3.33	
	340		3.28	
	360		3.24	
	380		3.20	
	400		3.17	
	444		3.14	<.005

Zinc sulfide

Eastman Kodak

(IRTRAN 2), 8.5 GHz, 24°C, density = 4.081 g/cm³

 $\kappa' = 8.43$; $\tan \delta = .00160$

24 GHz

T°C	κ	$\tan \delta$	T°C	κ	$\tan \delta$
25	8.32	.00170	600	9.32	.0069
100	8.44	.00172	650	9.56	.0148
200	8.61	.00175	700	9.75	.0244
300	8.79	.0019	730	9.92	.033
400	9.00	.0025	750	10.03	.037
500	9.24	.0029			

Zirconia fiber products

Zircoa

24 GHz, 24°C

	κ	$\tan \delta$
"ZIRCAR" Type ZYW-30A	2.63	.0082
"ZIRCAR" Type ZYF-100	1.474	.0014

II. Miscellaneous Inorganics

"Pyroceram" 9606

Corning

Measurements on a group of 12 samples received in December 1977 from
General Dynamics and one sample from Raytheon

Standing-wave measurements at 8.515 GHz, 24°C

Sample No.	Diameter (inches)	Face 1		Face 2		Density (g/cm³)	
		K	tan δ	Diameter (inches)	K	tan δ	
1 BH	.9993	5.5426	.00023	.9996	5.5418	.00022	
1 OP		5.5457	.00020		5.5436	.00022	
2 BH	1.0005	5.5382	.00018	1.0007	5.5389	.00018	
3	1.0004	5.5430	.00020	1.0003	5.5431	.00019	
4	.9992	5.5395	.00021	.9994	5.5405	.00021	
5	.9998	5.5456	.00020	.9998	5.5465	.00020	
6.	.9993	5.5481	.00022	.9993	5.5457	.00020	2.5933
7	.9996	5.5396	.00021	.9997	5.5414	.00022	
8	1.0000	5.5421	.00021	1.0003	5.5415	.00021	2.5914
9	.9998	5.5446	.00021	1.0000	5.5442	.00021	2.5929
10	1.0003	5.5428	.00021	1.0005	5.5448	.00021	2.5927
11	.9987	5.5359	.00023	.9992	5.5362	.00022	2.5898
12	.9997	5.5469	.00021	.9997	5.5461	.00020	2.5922

"BH" - Sample measured against bottom of sample holder.

"OP" - Sample measured a quarter wavelength from end using a polystyrene tube spacer.

Resonant-cavity measurements at approx. 8.5 GHz

T°F	#1		#2		#3		#4			
	K	tan δ	T°F	K	tan δ	K	tan δ	T°F	K	tan δ
67	5.542	.00023	69	5.539	.00020	5.543	.00020	74	5.540	.00021
300	5.586	.0003	300	5.581	.00029	5.585	.00030	300	5.584	.0004
600	5.643	.0007	600	5.635	.0008	5.639	.0008	600	5.636	.0010
900	5.714	.0021	900	5.701	.0014	5.712	.0016	900	5.713	.0018
1200	5.80	.0052	1200	5.784	.0045	5.79	.0045	1200	5.785	.0054

	#5		#7		#8		#9			
	T°F	K	T°F	K	tan δ	T°F	K	tan δ		
72	5.546	.0002	72	5.541	.0002	5.542	.0002	72	5.544	.0002
300	5.588	.0004	300	5.586	.0003	5.584	.0004	300	5.589	.0004
600	5.646	.0010	600	5.647	.0006	5.643	.00115	600	5.649	.0012
900	5.710	.0015	900	5.709	.0014	5.710	.0023	900	5.713	.0028
1200	5.793	.0045	1200	5.781	.0052	5.790	.0043	1200	5.786	.0056

'Pyroceram' 9606 (cont.)

Resonant-cavity measurements at approx. 8.5 GHz (cont.)

#10			#12		
T°F	K	tan δ	T°F	K	tan δ
72	5.544	.0002	70	5.546	.0002
300	5.589	.0004	300	5.589	.0004
600	5.649	.0008	600	5.646	.0010
900	5.715	.0018	900	5.714	.0021
1200	5.792	.0059	1200	5.798	.0058

#11			#6			Raytheon	
T°F	K	tan δ	K	tan δ	K	tan δ	
74	5.536	.00022 ± 5	5.547	.00022 ± 5	5.661	.0003 ± 1	
300	5.581	.00028 ± 5	5.587	.00030 ± 5	5.697	.0005 ± 1	
600	5.643	.0007 ± 2	5.642	.00053 ± 7	5.751	.0010 ± 2	
900	5.718	.0018 ± 4	5.708	.0014 ± 2	5.808*	.0019* ± 4	
1200	5.81	.0041 ± 5	5.79	.0042 ± 4			

Error in right digit shown for tan δ

Error in K ± .002 except at 1200°F ± .03

* Extrapolated from run to 752°F

Average values for 12 samples from Gen. Dynamics

Dec. 1977, densities: 2.5898 to 2.5933 gm/cm³

From Raytheon Nov. 1979:

8.5 GHz				8.5 GHz			
T°F	T°C	K	D.F.	T°F	T°C	K	D.F.
73	23	5.542	.00021	73	22.6	5.619	.00028
300	149	5.586	.0003	212	100	5.649	.00033
600	316	5.643	.0009	392	200	5.683	.00060
900	482	5.711	.0018	572	300	5.720	.00105
1200	649	5.79	.0049	752	400	5.760	.00165
				932	500	5.804	.00263
				1112	600	5.847	.00388
				1292	700	5.888	.00567
				1400	760	5.915	.0070
				1472	800	5.932	.0082

"Pyroceram" 9606, continued

From Gen. Dynamics July 1978:

8.5 GHz

T°C	K	D.F.
22.3	5.419	.00030
100	5.453	.00047
200	5.501	.00069
299	5.549	.00097
400	5.601	.00139
500	5.661	.00197
600	5.725	.00294
700	5.781	.00469
750	5.814	.00569
810	5.864	.00734

"Pyroceram" 960Q Corning
Sample from Gen. Dynamics July 1978

8.5 GHz

T°F	T°C	K	D.F.
73	23	6.268	.00024
122	50	6.259	.00022
176	80	6.254	.00022
212	100	6.257	.00024
248	120	6.262	.00026
284	140	6.270	.00029
338	170	6.282	.00033
392	200	6.296	.00042
572	300	6.334	.00050
752	400	6.377	.00098
932	500	6.424	.00236
1112	600	6.477	.0044
1292	700	6.542	.0074
1472	800	6.615	.0113
1517	825	6.638	.0124

Pyroceram 960Q Sample from General Dynamics 1980

8.515 GHz

24 GHz

T°C	K	tan δ	T°C	K	tan δ
25	6.228	.00027	21	6.173	.00032
100	6.209	.00025		6.157	.0004
200	6.206	.00041		6.164	.0005
300	6.215	.00070		6.179	.0006
400	6.236	.00140		6.198	.0010
500	6.265	.00295		6.227	.0020
600	6.296	.0060		6.275	.0050
700	6.321	.0112		6.338	.013
800	6.35	.018		6.40	.020

"Pyroceram" 960Z

Corning

Sample from Gen. Dynamics July 1978

8.5 GHz

T°C	K	D.F.
23.1	5.732	.00026
90	5.771	.00038
150	5.811	.00053
231	5.861	.00074
297	5.901	.00095
350	5.938	.00118
435	5.999	.00169
525	6.064	.00278
585	6.107	.00370
653	6.164	.00550
690	6.188	.00655
730	6.218	.00805
765	6.242	.00966
800	6.272	.0115

Samples from Gen. Dynamics 1980

8.5 GHz

24 GHz

T°C	K	D.F.	K	D.F.
21	5.688	.00024	5.663	.00062
100	5.737	.00052	5.695	.0005
200	5.795	.00097	5.743	.0008
300	5.853	.00208	5.790	.0012
400	5.919	.00305	5.843	.0017
500	5.987	.0054	5.900	.0028
600	6.054	.0105	5.960	.0048
700	6.132	.0162	6.030	.0076
800	6.19	.034	6.11	.012

Pipe Insulating Compound, fresh mix

Lebanon Steel Foundry

2.15 GHz

T°F	K	D.F.	T°F	K	D.F.	Composition:
77	14.3	.15	500	1.22	.0096	Perlite 82 grams
100	14.3	.18	600	1.23	.012	SSF 5 grams
150	14.0	.22	700	1.24	.016	Water 23 ml
200	13.6	.24	800	1.26	.021	Silicate 87 grams
water lost, unstable			900	1.28	.028	ZnO 13 grams
			1000	1.30	.040	
300	2.8	.026	1100	1.33	.056	
350	1.21	.0074	1200	1.38	.081	
400	1.21	.0079				

Chimney Flue Liner

Sample from MIT, Melcher

D.C. conductivity (one-minute) versus temperature

T°C	Sigma, mho/cm	T°C	Sigma, mho/cm	T°C	Sigma, mho/cm
22.5	4.40E-13	217.5	2.45E-10	583	5.53E-6
33	3.94E-14	232.6	4.88E-10	653	1.19E-5
55	1.33E-13	281	2.64E-9	704	1.88E-5
85	5.44E-13	302.5	5.11E-9	751	2.95E-5
103.5	1.22E-12	411	1.21E-7	793	4.37E-5
137	5.19E-12	495	5.44E-7	841	6.83E-5
161	1.53E-11	12hrs at 245°C		907	1.24E-4
192	7.42E-11	439	2.08E-7	969	1.90E-4
199	1.13E-10	576	5.04E-6	982	2.05E-4

CHIMNEY FLUE LINER

VOL/00/T	T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3824	22.5	100.	5.254	0.793128	0.150943	0.44063E-10
3.3824	22.5	1000.	5.013	0.190604	0.038022	0.10589E-09
3.3824	22.5	10000.	4.902	0.076039	0.015511	0.42244E-09
3.3824	22.5	100000.	4.728	0.048433	0.010244	0.26907E-08
3.3824	22.5	1000000.	4.677	0.038693	0.008273	0.21496E-07
3.3824	22.5	9500000.	4.586	0.037590	0.008196	0.19839E-06
2.6799	100.0	100.	5.831	0.634580	0.108831	0.35254E-10
2.6799	100.0	1000.	5.316	0.336510	0.063298	0.18695E-09
2.6799	100.0	10000.	5.041	0.157745	0.031295	0.87636E-09
2.6799	100.0	100000.	4.892	0.093367	0.019087	0.51870E-08
2.6799	100.0	1000000.	4.767	0.067494	0.014160	0.37497E-07
2.6799	100.0	9500000.	4.703	0.054057	0.011495	0.28530E-06
2.1135	200.0	100.	11.029	8.651924	0.784484	0.48066E-09
2.1135	200.0	1000.	7.353	2.188744	0.297670	0.12160E-08
2.1135	200.0	10000.	5.963	0.751230	0.125976	0.41735E-08
2.1135	200.0	100000.	5.377	0.330298	0.061433	0.18350E-07
2.1135	200.0	1000000.	5.041	0.176863	0.035083	0.98257E-07
2.1135	200.0	9500000.	4.872	0.105327	0.021619	0.55589E-06
1.7447	300.0	100.	45.871	216.696243	4.724037	0.12239E-07
1.7447	300.0	1000.	18.303	30.440948	1.663164	0.16912E-07
1.7447	300.0	10000.	9.921	5.454198	0.549772	0.30301E-07
1.7447	300.0	100000.	6.811	1.675701	0.246042	0.93094E-07
1.7447	300.0	1000000.	5.654	0.607396	0.107423	0.33744E-06
1.7447	300.0	9500000.	5.025	0.275409	0.054803	0.14535E-05
1.4856	400.0	100.	203.086	3021.52686	14.878033	0.16786E-06
1.4856	400.0	1000.	55.502	314.027588	5.657909	0.17446E-06
1.4856	400.0	10000.	20.490	39.550461	1.930255	0.21972E-06
1.4856	400.0	100000.	10.048	7.160682	0.712662	0.39782E-06
1.4856	400.0	1000000.	6.826	1.731097	0.253602	0.96172E-06
1.4856	400.0	9500000.	5.554	0.569652	0.102563	0.30065E-05
1.2934	500.0	1000.	146.175	1804.77759	12.346718	0.10027E-05
1.2934	500.0	10000.	45.371	232.481750	5.124066	0.12916E-05
1.2934	500.0	100000.	18.036	33.052612	1.832572	0.18363E-05
1.2934	500.0	1000000.	9.184	6.321146	0.688289	0.35117E-05
1.2934	500.0	9500000.	6.103	1.639059	0.268581	0.86506E-05

8.5GHz 24°C as received, K=4.95, D.F.=.026; dry, K=4.81, D.F.=.012

New Jersey Sand #2, initial H₂O 4.25%

M.I.T., Melcher

Sigma, d.c. conductivity mho/cm

T°C	Sigma	T°C	Sigma	T°C	Sigma
28	2.11E-10	48 hours drying		475	2.02E-9
50	3.93E-10	63	2.09E-13	490	4.18E-9
79	1.01E-11	143	1.02E-13	549	2.20E-8
95	4.73E-12	229	7.99E-13	609	1.14E-7
127	5.97E-13	269	2.61E-12	705	8.65E-7
146	7.21E-13	328	1.84E-11	747	2.73E-6
216	1.11E-12	395	1.25E-10	831	4.56E-6
270	5.28E-12				

III. Organics

"Laminec" 4123

American Cyanamid

25°C	Freq., MHz	κ'	$\tan \delta$
	10	3.71	.0167
	30	3.64	.0166

IL-T001 Absorber

TDK Industries
Sample from Army Materials and Mechanics
Research Center (AMMRC)

Frequency, GHz	1	1.685	2.45	3	5	8.5
κ'	47.	43.	41.2	39.	36.	35.
$\tan \delta$	.104	.091	.102	.1445	.125	.085
μ'/μ_0	4.03	2.84	2.11	1.785	1.064	.85
$\tan \delta_m$	.687	.937	1.20	1.218	1.585	1.29
α , att. db/cm	9.56	16.28	24.5	28.2	41.5	51.6

Ferrite-Epoxy Resin Mixtures

AMMRC

FP-4 50 wt% ferrite

GHz	1	1.685	2.45	3	5	8.5	14	24
κ'	4.469	4.328	4.178	3.153	4.119	3.950	3.92	3.90
$\tan \delta$	.0947	.0883	.0874	.0825	.0819	.0620	.0512	.046
μ'/μ_0	1.294	1.219	1.160	1.121	.979	.963	.989	1.00
$\tan \delta_m$	.0669	.1703	.1858	.1984	.190	.0528	.0163	.005

MAG-20 50 wt% 20 mesh magnetite

κ'	25.7	25.4	24.2	23.6	23.1	13.1	17.2	23.9
$\tan \delta$	.111	.109	.116	.114	.101	.0475	.03	.03
μ'/μ_0	1.75	1.57	1.44	1.37	1.12	.937	.897	1.03
$\tan \delta_m$	.276	.325	.378	.423	.515	.579	.49	.30

MAG-65 50 wt% 65 mesh magnetite

κ'	16.84	16.5	16.46	16.3	16.25	16.16	18.8*
$\tan \delta$	.0624	.0633	.0624	.0656	.075	.091	.0593*
μ'/μ_0	1.765	1.611	1.495	1.453	1.242	.985	2.149*
$\tan \delta_m$	.203	.254	.309	.326	.36	.419	.0979*

*freq. = 300 MHz

"Nylon" 66

E. I. Dupont de Nemours and Co.

As Received, .559% water

After vacuum drying, 2 days, 68°C

Time, sec.	Freq., Hz	σ mho/cm
	1000	4.96E-11
	100	3.84E-12
60	.00265	6.95E-15
300	.0053	4.15E-15
778	.00020	2.59E-15
2400	.000066	1.66E-15

Time, sec.	Freq., Hz	σ mho/cm
	1000	2.61E-11
	100	2.14E-12
	20	3.17E-13
60	.00265	7.31E-17
120	.00133	5.41E-17
180	.00098	3.90E-17
300	.00053	2.98E-17

Frequencies less than 20 Hz calculated as $1/(2\pi t)$; this assumes charging current is negligible at these times.

"Nylon" 66

E. I. Dupont de Nemours and Co.
Sample molded by AMP

Water Content = .13%

T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
25.0	10.	3.662	0.017556	0.004794	0.97532E-13
25.0	20.	3.647	0.019707	0.005404	0.21896E-12
25.0	30.	3.642	0.021817	0.005990	0.36362E-12
25.0	50.	3.633	0.023715	0.006528	0.65876E-12
25.0	100.	3.618	0.027065	0.007480	0.15036E-11
25.0	200.	3.575	0.038884	0.010875	0.43204E-11
25.0	300.	3.566	0.042309	0.011863	0.70515E-11
25.0	500.	3.563	0.048911	0.013727	0.13586E-10
25.0	1000.	3.546	0.053687	0.015141	0.29826E-10
25.0	2000.	3.514	0.064390	0.018323	0.71545E-10
25.0	3000.	3.483	0.067870	0.019484	0.11312E-09
25.0	5000.	3.443	0.073324	0.021296	0.20368E-09
25.0	10000.	3.403	0.076979	0.022619	0.42766E-09
25.0	20000.	3.388	0.078724	0.023238	0.87472E-09
25.0	50000.	3.370	0.075890	0.022521	0.21081E-08
25.0	100000.	3.338	0.073176	0.021923	0.40653E-08
25.0	200000.	3.305	0.069027	0.020888	0.76697E-08
25.0	300000.	3.295	0.067828	0.020585	0.11305E-07
25.0	500000.	3.272	0.067459	0.020620	0.18739E-07
25.0	1000000.	3.247	0.063208	0.019468	0.35115E-07
25.0	2000000.	3.218	0.065476	0.020345	0.72752E-07
25.0	3500000.	3.200	0.067161	0.020990	0.13059E-06
25.0	6000000.	3.181	0.066853	0.021019	0.22284E-06
25.0	9500000.	3.154	0.066478	0.021075	0.35086E-06
25.0	30000000.	3.145	0.067829	0.021566	0.11305E-05

Water Content = .23%

T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
25.0	5.	4.413	0.108300	0.024539	0.30083E-12
25.0	10.	4.364	0.102985	0.023598	0.57214E-12
25.0	20.	4.316	0.098521	0.021276	0.10947E-11
25.0	30.	4.285	0.098263	0.022932	0.16377E-11
25.0	50.	4.229	0.098553	0.023304	0.27376E-11
25.0	100.	4.208	0.101789	0.024190	0.56549E-11
25.0	200.	4.119	0.123972	0.030094	0.13775E-10
25.0	300.	4.117	0.127763	0.031036	0.21294E-10
25.0	500.	4.067	0.135662	0.033354	0.37684E-10
25.0	1000.	4.014	0.143965	0.035868	0.79981E-10
25.0	2000.	3.957	0.148788	0.037600	0.16532E-09
25.0	3000.	3.918	0.154694	0.039479	0.25782E-09
25.0	5000.	3.868	0.155900	0.040306	0.43306E-09
25.0	10000.	3.795	0.160411	0.042272	0.89117E-09
25.0	20000.	3.724	0.158407	0.042539	0.17601E-08
25.0	50000.	3.635	0.151328	0.041632	0.42035E-08
25.0	100000.	3.574	0.141872	0.039696	0.78818E-08
25.0	200000.	3.507	0.128033	0.038610	0.14226E-07
25.0	300000.	3.477	0.121737	0.035016	0.20290E-07
25.0	500000.	3.450	0.113173	0.032808	0.31437E-07
25.0	1000000.	3.378	0.103135	0.030535	0.57297E-07
25.0	2000000.	3.358	0.091325	0.027190	0.10147E-06
25.0	3000000.	3.324	0.085876	0.025836	0.16698E-06
25.0	6000000.	3.297	0.083500	0.025323	0.27833E-06
25.0	9500000.	3.275	0.078812	0.024063	0.41595E-06
25.0	30000000.	3.259	0.072724	0.022316	0.12121E-05

AL-300, polyimide laminate

Atlantic Laminates

8.5 GHz

T°C	K	D.F.	T°C	K	D.F.
26	4.65	.0192	179	4.64	.0238
48	4.71	.0203	212	4.64	.0238
71	4.69	.0212	237	4.57	.0220
96	4.70	.0230	259	4.58	.0229
123	4.72	.0235	279	4.58	.0229
148	4.65	.0228	26	4.39	.0103

"Avcoat" 8029

AVCO

Thickness (cm)	8.5 GHz			Thickness (cm)	Thickness		
	T°C	K	D.F.		T°C	K	D.F.
3.189	25	2.267	.00079	3.228	25		
3.202	60.5	2.257	.00079			reheated	
3.210	108	2.244	.00101	3.469	348	2.019	.0022
3.215	136	2.234	.00116	3.949	406	1.896	.00235
3.241	189	2.214	.00130	4.197	450	1.805	.00218
3.276	224	2.198	.00148	4.415	485	1.756	.00200
3.377	278	2.160	.00172	5.037	509	1.44	.0027
3.432	300	2.142	.00188			liquid with bubbles	
3.771	343	2.055	.0021				

AVCO K96 sample one

AVCO

T°C	8.5 GHz			Thickness (cm)	E parallel to hot pressing dir.		
	K	tan δ	E perpendicular to hot pressing dir.		K	tan δ	E parallel to hot pressing dir.
20.3	2.464	.00207		1.9350	2.383	.00160	
64.3	2.453	.00203		1.9424	2.375	.00187	
101	2.441	.00210		1.9504	2.362	.00173	
148	2.432	.00212		1.9559	2.351	.00165	
203	2.406	.00221		1.9711	2.326	.00091	
250	2.347	.00239		2.0239	2.265	.00115	
303	2.056	.00250		2.3077	1.980	.00133	
347				~ 2.56			

sample two, E perpendicular to hot pressing direction

T°C	K	tan δ	Thick.cm	T°C	K	tan δ	Thick.cm
20.2	2.448	.00150	2.2110	288	2.368	.00143	2.3187
57	2.443	.00136	2.2200	325	2.345	.00145	2.3522
84	2.436	.00140	2.2295	350	2.033	.00133	2.8405
101	2.431	.00132	2.2356	380	1.951	.00204	2.9830
130	2.424	.00130	2.2452	400	1.431	.00201	3.3168
148	2.418	.00127	2.2533	431	1.879	.00190	3.3124
188	2.399	.00100	2.2682	474	1.843	.00208	3.4829
208	2.390	.00112	2.2797	509	1.645	.00273	3.7028
248	2.385	.00136	2.2909				

Dielectric insulation boards

23°C

Cincinnati Milacron

Sample designation	Freq., Hz	1 M	10 M	100 M	300 M	1 G	3 G	8.5 G	14 G	24 G
PC-75	κ	4.14	3.94	3.68	3.64	3.61	3.59	$3.568 \pm .02$	3.556	3.54
	$\tan \delta$	.0272	.0358	.0378	.0370	.0324	.0289	.0245	.0250	.026
65M62	κ	4.40	4.22	3.96	3.89	3.81	3.755	$3.715 \pm .01$	3.700	3.685
	$\tan \delta$	.0305	.0377	.0415	.0394	.0358	.0304	.0256	.0269	.029
NP424	κ	4.49	4.22	3.85	3.89	3.82	3.76	$3.710 \pm .2$	3.692	3.68
	$\tan \delta$	.0399	.044	.0455	.0449	.0394	.0337	.0300	.0312	.040
FR-4*	κ	4.58	4.46	4.33	4.53	4.48	4.46	$4.445 \pm .02$	4.42	4.38
	$\tan \delta$	.0200	.0202	.0187	.0155	.0146	.0143	.0146	.0150	.016
MILCLAD	κ	4.11	4.02	3.94	3.93	3.92	3.92	$3.914 \pm .01$	3.912	3.90
CA7FR	$\tan \delta$	.0118	.0130	.0132	.0127	.0115	.0105	.0099	.00985	.011
CIMCLAD	κ	3.86	3.78	3.69	3.76	3.71	3.675	$3.645 \pm .01$	3.635	3.625
MA*	$\tan \delta$	.0126	.0114	.0110	.0109	.0105	.00928	.00888	.0095	.0105
CIMCLAD	κ	4.17	4.09	3.99	3.98	3.96	3.94	$3.929 \pm .02$	3.917	3.91
MA7FR	$\tan \delta$	.0115	.0131	.0133	.0126	.0116	.0110	.0106	.0105	.0108
CIMCLAD	κ	4.10	4.01	3.92	3.89	3.85	3.85	$3.839 \pm .006$	3.83	3.82
ACAFR	$\tan \delta$	.0122	.0135	.0142	.0137	.0114	.0104	.00995	.0103	.0109

1, 10, 100 M \pm sheet; higher frequencies, \pm H.

*These are not isotropic within 1% in κ .

"Ethofoam" .0381 gm/cm³

Dart Industries
Sample from Sperry

Freq., GHz	K	D.F.
3	1.042	<.0001
8.5	1.042	.00001 \pm .00001

"Rulon" II

Dixon Industries

Freq., Hz	DC, 1 minute	24°C, Freq. run									
		60	100	1 K	10 K	100 K	1 M	10 M	1 G	2.45 G	3 G
κ'		3.00	3.00	2.99	2.99	2.98	2.98	2.97	2.863	2.850	2.840
κ''		.0103	.0103	.00703	.00526	.00462	.00343	.00285	.00472	.00485	.00517
$\tan \delta$		.00344	.00342	.00235	.00176	.00155	.00115	.00096	.00165	.00170	.00182
σ mho/cm	1.3M-16	3.44E-13	5.7E-13	3.90E-12	2.92E-11	2.57E-10	1.90E-9	1.58E-8	2.62E-6	6.6E-6	3.61E-6
ρ ohm/cm	6.6E-15										

Temperature run

Freq., GHz	1.			2.45			3.			$10^6 \times$ σ
	T°C	κ'	κ''	$\tan \delta$	$10^6 \times$ σ	κ'	κ''	$\tan \delta$	$10^6 \times$ σ	
26	2.863	.00472	.00163	2.62	2.850	.00485	.00170	6.60	2.840	.00517
74	2.856	.00503	.00176	2.79	2.839	.00520	.00183	7.07	2.832	.00566
109	2.854	.00603	.00212	3.36	2.835	.00641	.00226	8.72	2.827	.00732
136	2.852	.00915	.00321	5.9	2.833	.00904	.00319	12.3	2.824	.0105
173	2.851	.0131	.00531	8.41	2.829	.0131	.00533	20.5	2.819	.0164
205	2.855	.0225	.00787	12.5	2.827	.0216	.00765	29.4	2.817	.0228
250	2.848	.0280	.00975	15.5	2.829	.0274	.00969	37.3	2.819	.0290
22	2.844	.00435	.00153	2.42	2.838	.00400	.00141	5.45		.0103

"Kevlar" laminates

E. I. Dupont de Nemours and Co.
Samples from Sperry

After 21-1/2 days 95% R.H.

		K	$\tan \delta$	wt. %
#1	Face 1	0	4.16	.113
#2	Face 1	0	3.93	.0772
#3	Face 1	0	4.19	.103
#4	Face 1	0	3.78	.0799
				3.485

"Kevlar" laminates, continued As Received

Against short

Over $\lambda/4$

Sample		Rotation (degrees)	κ	$\tan \delta$	%H ₂ O	κ	$\tan \delta$
#1	Face 1	0	4.24	.0534	3.505	4.098	.0707
		90	4.08	.0756			
	Face 2	0	4.05	.084	4.176	4.176	.0736
		90	4.11	.0819			
#2	Face 1	0	3.65	.0369	2.613	2.613	2.613
		90	3.72	.0357			
#3	Face 1	0	4.17	.0886	3.677	3.677	3.677
		90	4.24	.0895			
#4	Face 1	0	3.59	.0478	2.784	2.784	2.784
		90	3.72	.0451			

Dried 2-1/2 days 80°C vac. oven

#1	0	3.35	.0092
	90	3.38	.0083
#2	0	3.37	.0109
	90	3.44	.0089
#3	0	3.43	.0110
	90	3.47	.0099
#4	0	3.20	.0103
	90	3.29	.0087

45 hours 95% R.H. Desiccator

#1	0	3.84	.0661	3.039
	90	3.92	.0672	
#2	0	3.62	.0318	2.019
	90	3.70	.0311	
#3	0	3.79	.0500	2.575
	90	3.84	.0503	
#4	0	3.60	.0465	2.637
	90	3.73	.0448	

Intermediate desiccation

for Sample #3	Hours	Rotation (degrees)	κ	$\tan \delta$	wt. %
69		0	3.88	.0583	2.931
		90	3.93	.0585	
100					3.228
					3.465

"Kevlar" Ropes

E. I. Dupont de Nemours and Co.

FR is frequency in Hz

Rope A, 24°C, 50% R.H.

FR	K1	K2	TAN DELTA	SIGMA
50.	6.6255	0.528094	0.079706	0.14669E-10
100.	5.9849	0.411533	0.068762	0.22863E-10
1000.	5.7568	0.334317	0.058074	0.18573E-09
10000.	5.2008	0.266940	0.051268	0.14830E-08
100000.	4.7625	0.300517	0.063100	0.16695E-07
1000000.	4.4191	0.303765	0.068739	0.16876E-06
9500000.	4.3046	0.316421	0.073507	0.16700E-05
30000000.	3.6555	0.304161	0.083207	0.50694E-05

Rope A, 120°C

FR	K1	K2	TAN DELTA	SIGMA
60.	21.033	53.21245	2.52997	0.17737E-08
100.	15.918	29.27719	1.83929	0.16265E-08
1000.	6.407	5.25332	0.81997	0.29185E-08
10000.	4.772	0.85355	0.17885	0.47419E-08
100000.	4.560	0.19611	0.04301	0.10895E-07
1000000.	4.209	0.15851	0.03766	0.88062E-07
9500000.	4.025	0.16402	0.04075	0.86569E-06

Rope B, 24°C, 50% R.H.

FR	K1	K2	TAN DELTA	SIGMA
50.	7.6933	0.875021	0.113738	0.24306E-10
100.	7.5078	0.640551	0.085318	0.35586E-10
1000.	6.9986	0.444717	0.063543	0.24706E-09
10000.	6.0960	0.323863	0.053128	0.17992E-08
100000.	5.5494	0.346957	0.062522	0.19275E-07
1000000.	5.1731	0.392599	0.075892	0.21811E-06
9500000.	4.8283	0.406893	0.084272	0.21475E-05
30000000.	4.1279	0.411350	0.099650	0.68558E-05

Rope B, 120°C

FR	K1	K2	TAN DELTA	SIGMA
50.	26.353	66.87852	2.53784	0.18577E-08
60.	23.345	57.07668	2.44490	0.19026E-08
100.	16.986	39.67288	2.33562	0.22040E-08
1000.	5.527	6.04871	1.09446	0.33604E-08
10000.	4.982	0.78675	0.15793	0.43708E-08
100000.	4.783	0.17227	0.03602	0.95707E-08
1000000.	4.691	0.11827	0.02521	0.65705E-07
9500000.	4.588	0.14783	0.03222	0.78019E-08

"Kevlar" Ropes, continued

Rope C, 24°C, 50% R.H.

FR	K1	K2	TAN DELTA	SIGMA
50.	12.3266	1.799829	0.146012	0.49995E-10
100.	11.6037	1.436832	0.123825	0.79824E-10
1000.	9.5361	1.285998	0.134856	0.71444E-09
10000.	8.0059	0.964711	0.120500	0.53595E-08
100000.	6.8165	0.687531	0.100863	0.38196E-07
1000000.	5.6022	0.653690	0.116684	0.36316E-06
9500000.	4.9611	0.742388	0.149642	0.39182E-05
30000000.	3.9680	0.689153	0.173678	0.11486E-04

Rope C, 120°C

FR	K1	K2	TAN DELTA	SIGMA
50.	36.390	160.49568	4.41044	0.44582E-08
60.	27.560	128.04948	4.64614	0.42693E-08
100.	23.815	89.23180	3.74686	0.49573E-08
1000.	7.197	12.34859	1.71576	0.68603E-08
10000.	5.520	1.78799	0.32393	0.99333E-08
100000.	4.989	0.39323	0.07881	0.21846E-07
1000000.	4.886	0.22794	0.04665	0.12663E-06
9500000.	4.441	0.27151	0.06114	0.14329E-05

Rope D, 24°C, 50% R.H.

FR	K1	K2	TAN DELTA	SIGMA
50.	10.3523	1.177239	0.113718	0.32701E-10
100.	10.1137	0.912032	0.090178	0.50668E-10
1000.	9.4470	0.800575	0.084744	0.44476E-09
10000.	8.0265	0.950508	0.118422	0.52806E-08
100000.	6.4204	0.921320	0.143320	0.51184E-07
1000000.	5.0137	0.617431	0.123148	0.34302E-06
9500000.	4.5359	0.532482	0.117392	0.28103E-05
30000000.	3.6717	0.476469	0.129768	0.79412E-05

Rope D, 120°C

FR	K1	K2	TAN DELTA	SIGMA
50.	34.260	127.21927	3.71333	0.35339E-08
60.	30.668	110.98825	3.61901	0.36996E-08
100.	22.945	87.83615	3.82816	0.48798E-08
1000.	7.334	10.14525	1.38328	0.56362E-08
10000.	5.576	1.54414	0.27692	0.85786E-08
100000.	5.013	0.33321	0.06846	0.18512E-07
1000000.	4.956	0.19092	0.03853	0.10607E-06
9500000.	4.625	0.24093	0.05209	0.12716E-05

"Mylar" 2-ply, corrugated

E. I. Dupont de Nemours and Co.

Frequency, MHz	K	D.F.
1	1.114	.00507
10	1.107	.00512
20	1.106	.00480
30	1.106	.00380

"Riston", exposed film

E. I. Dupont de Nemours and Co.

Freq., MHz	1	10	100	1000	8515
K	3.31	3.12	2.97	2.85	2.77
D.F.	.042	.039	.0326	.0272	.0182

"Sclair" polyethylene
#8307-UV#5

Dupont of Canada

24 GHz 22°C

K = 2.33 ± .02 D.F. = .00027 ± .00008

After 1500 hours in Atlas Weatherometer:

K = 2.30 ± .02 D.F. = .00041 ± .00003

"Tefzel"

E. I. Dupont de Nemours and Co.

8.5 GHz 23°C K = 2.328 ± .011 D.F. = .0117

"Eccofloat"

Emerson and Cuming

8.5 GHz 24 °C

EF38A, .6002 gm/cm³ K = 1.8605 D.F. = .0128
EF38B, .4833 gm/cm³ K = 1.8401 D.F. = .0121

"Eccofoam" HiK 625

Emerson and Cuming

24 GHz 24°C K = 6.0 D.F. = .045

"Stycast" 1.9

Emerson and Cuming
Sample from MIT, RLE

8.5 GHz 24°C K = 1.71 D.F. = .0055

"Esscolam" VI 8166

ESSCO

Sample from Raytheon

The temperature run was made with stacked disks at 8.5 GHz. The thickness shown is the stack height divided by the number of pieces and includes expansion due to trapped decomposition gases.

Excess phase

T°C	K	D.F.	Thick.,cm	Atten.,db	Insertion loss,db	shift (deg.)
25	2.943	.0158	.063	.00789	.0587	.058
49	2.843	.0216	.0664	.0114	.0621	.065
73	2.835	.0292	.0669	.0155	.0665	.067
107	2.84	.047	.0677	.0252	.0779	.071
129	3.032	.0304	.0696	.0169	.0343	.086
163	3.129	.0764	.0676	.0410	.1112	.088
179	2.744	.0723	.0754	.0432	.1018	.090
198	2.748	.0569	.0784	.0355	.0988	.103
233	1.664	.0283	.1139	.0253	.0446	.091
245	2.165	.0251	.0909	.0180	.0559	.096
258	2.817	.0426	.0760	.0258	.0900	.098
272	3.02	.0527	.0731	.0307	.1042	.102
300	3.09	.0418	.0735	.0246	.1040	.107

"Lexan" General Purpose Grade, clear

Freq., Hz	Frequency Runs at 25°C										
	10 ²	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ⁸	3x10 ⁸	10 ⁹	3x10 ⁹	8.5x10 ⁹
Lexan, clear											
κ	3.006	3.004	3.003	2.986	2.971	2.922	2.797	-	2.780	2.773	-
$\tan \delta$	.00056	.00065	.00132	.006405	.00649	.0111	.0103	-	.00643	.00515	-

"Lexan" 500, polycarbonate

R.T. 8.5 GHz		24 GHz		
K	D.F.	T°C	K	D.F.
2.921	.00568	24.4	2.881	.00625
		62.3	2.872	.00734
		68.3	2.871	.00739

"Noryl" (s)

Freq., Hz	Frequency Runs at 25°C										
	10 ²	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ⁸	3x10 ⁸	10 ⁹	3x10 ⁹	8.5x10 ⁹
Noryl N300											
κ	2.791	2.779	2.767	2.751	2.736	2.717	2.71	2.73	2.726	2.723	2.720
$\tan \delta$	.00324	.00357	.00388	.00347	.00322	.00252	.00241	.00266	.00356	.00436	.00575
Noryl RN300											
κ	3.044	3.117	3.081	3.048	3.020	2.982	2.976	3.065	3.062	3.057	3.050
$\tan \delta$	.00637	.00669	.00697	.00673	.00573	.00409	.00418	.00479	.00578	.00644	.00691
Noryl NM240											
κ	3.059	3.034	3.002	2.981	2.960	2.938	2.927	3.062	3.057	3.052	3.046
$\tan \delta$	.00702	.00649	.00581	.00469	.00385	.00289	.00280	.00320	.00380	.00365	.00324

Note: Electric field is perpendicular to faces of injection molded Noryl disks in the frequency range 10² to 10⁸ Hz;
at higher frequencies electric field is parallel to faces of disks.

"Noryl" undesignated

24 °C					
Freq., GHz	1	3	5	8.5	14
K	2.66	2.65	2.65	2.652	2.648
D.F.	.0020	.00310	.0036	.00396	.0058

PPO-534-801, polyphenylene oxide

R.T.	8.5 GHz		24 GHz		
	K	D.F.	T°C	K	D.F.
2.635	.00181		25	2.628	.00251
			62.2	2.622	.00257
			102.6	2.616	.00246
			139.7	2.599	.00253
			145.5	2.598	.00256
			184.5	2.515	.00269
			25	2.564	.00231

RTV's

24°C 8.5 GHz	
K	D.F.
#60, red	3.736
#630, grey	3.016
	.0172
	.0199

Marco 28C

R.T. 8.5 GHz

Grace Industries
Sample from Sperry

K D.F.

Sample #1 2.929 .0164
Sample #2 2.880 .0114

Polyethylene with olive drab pigment

Hardigg Industries

24 GHz 23°C K = 2.29 D.F. = .00062

Radome fabrics

Hoover Industries

22 °C 8.5 GHz

Averages for three samples:

K D.F. Thickness, cm

Grey 2.889 .0172 .059
White 2.895 .0174 .056

Polyethylene with 20 wt% gamma ferric oxide (<1μ) R.T. Hellerbond

Frequency, GHz	1	1.685	2.45	3
Dielectric Constant	2.6605		2.6576	2.6520
Dielectric Loss Tangent	.0025		.0018	.0015
Magnetic Permeability	1.1163	1.113	1.1099	1.0860
Magnetic Loss Tangent	.01287	.0389	.0684	.0821

Hercules PC-072-2 polypropylene

Hercules

R.T. 8.5 GHz	24 GHz	T°C	K	D.F.
K = 2.532		25	2.525	.00206
D.F. = .00217		62.1	2.511	.00222
		97.8	2.483	.00232
		133.2	2.441	.00246
		25	2.532	.00208

"Hycar" E4109

Hycar
Samples from Raytheon

T°C	K	D.F.	K	D.F.
Sample A 22	1.191	.0020	Sample B 1.178	.00196
125	1.201	.0062	1.186	.0054
25	1.190	.0021	1.175	.0020

"Thermocomp" DF1008

40% glass fiber reinforced polycarbonate

Liquid Nitrogen Proc. Corp.

23°C

Freq. MHz	1	10	100
K	3.81	3.79	3.73
D.F.	.00704	.0084	.00864

LNP-OF-1006 polyphenylene sulfide

LNP

R.T. 8.5 GHz	24 GHz			
K	D.F.	T°C	K	D.F.
3.762 .00406		25	3.709	.0055
		58.6	3.722	.0058
		85.8	3.715	.0063
		107.5	3.712	.0067
		135.8	3.677	.0078
		25	3.706	.0053

LNP-GF-1006 polysulfone

LNP

R.T.	8.5 GHz		24 GHz		
K	D.F.	T°C	K	D.F.	
3.613	.00763		25	3.532	.0087
			61.8	3.529	.0102
			83.8	3.526	.0107
			112.	3.516	.0112
			126.8	3.506	.0105
			138.3	3.494	.0104

"Loctite" LI-260

24°C

Loctite Corp.

Freq., Hz	100	1 k	10 k	100 k	1 M	10 M	8.5 G	14 G	24 G
ϵ'	4.568	4.459	4.319	4.093	3.716	3.356	2.409	2.404	2.394
ϵ''	.0851	.0888	.127	.200	.243	.230	.072	.0683	.0645
$\tan \delta$ (D.F.)	.0186	.0199	.0295	.0489	.0653	.0684	.0299	.0284	.02695
σ mho/cm	4.74E-12	4.94E-13	7.09E-10	1.11E-8	1.35E-7	1.28E-6	3.41E-4	5.31E-4	8.31E-4

Bondex 420

Loctite Corp.
Samples from Sperry

Sample #1 8.5 GHz			Sample #2 R.T.		
T°F	K	D.F.	Freq. GHz	3	5
74	2.855	.0128	K	3.07	3.05
139	2.90	.0168	D.F.	.025	.026
204	2.89	.0191			.027
					.0263

"Merlon" 1799 polycarbonate

Mobay Chemical Corp.

oven dry

1000/T	T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	20.	2.873	0.001810	0.000630	0.20113E-13
3.3653	24.0	50.	2.877	0.001600	0.000556	0.44455E-13
3.3653	24.0	100.	2.895	0.001456	0.000503	0.80886E-13
3.3653	24.0	200.	2.897	0.001821	0.000629	0.20235E-12
3.3653	24.0	500.	2.894	0.002099	0.000725	0.58299E-12
3.3653	24.0	1000.	2.905	0.002241	0.000771	0.12450E-11
3.3653	24.0	2000.	2.904	0.002507	0.000863	0.27854E-11
3.3653	24.0	5000.	2.904	0.003329	0.001146	0.92465E-11
3.3653	24.0	10000.	2.904	0.004523	0.001558	0.25128E-10
3.3653	24.0	20000.	2.895	0.005672	0.001960	0.63022E-10
3.3653	24.0	50000.	2.867	0.008290	0.002891	0.23027E-09
3.3653	24.0	100000.	2.839	0.010191	0.003590	0.56618E-09
3.3653	24.0	1000000.	2.835	0.022129	0.007807	0.12254E-07
3.3653	24.0	3000000.	2.876	0.015637	0.005438	0.26061E-08
3.3653	24.0	30000000.	2.845	0.026918	0.009462	0.44864E-07
3.3653	24.0	60000000.	2.893	0.027568	0.009529	0.91804E-07
3.3653	24.0	95000000.	2.904	0.029700	0.010228	0.15675E-06
3.3653	24.0	300000000.	2.899	0.029737	0.010256	0.49562E-06

"Merlon 1799 polycarbonate .15% water

Mobay

1000/T	T, DEG.C	FREQ.,Hz	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	5.	2.939	0.003736	0.001271	0.10378E-13
3.3653	24.0	10.	2.941	0.002830	0.000962	0.15721E-13
3.3653	24.0	20.	2.934	0.002222	0.000757	0.24685E-13
3.3653	24.0	50.	2.935	0.001623	0.000553	0.45090E-13
3.3653	24.0	100.	2.933	0.001461	0.000498	0.81140E-13
3.3653	24.0	300.	2.930	0.001685	0.000575	0.28082E-12
3.3653	24.0	1000.	2.931	0.002294	0.000783	0.12743E-11
3.3653	24.0	3000.	2.931	0.003168	0.001081	0.52803E-11
3.3653	24.0	10000.	2.927	0.004844	0.001655	0.26908E-10
3.3653	24.0	20000.	2.925	0.006437	0.002200	0.71524E-10
3.3653	24.0	50000.	2.922	0.009453	0.003235	0.26260E-09
3.3653	24.0	100000.	2.920	0.012359	0.004233	0.68661E-09
3.3653	24.0	1000000.	2.896	0.024580	0.008489	0.13655E-07
3.3653	24.0	3000000.	2.916	0.017691	0.006066	0.29485E-08
3.3653	24.0	30000000.	2.875	0.029417	0.010233	0.49029E-07
3.3653	24.0	9500000.	2.848	0.032089	0.011265	0.16936E-06
3.3653	24.0	30000000.	2.837	0.028328	0.009984	0.47214E-06

"Merlon 1799 polycarbonate .40% water

Mobay

1000/T	T, DEG.C	FREQ.,Hz	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	30000000.	2.831	0.035201	0.012434	0.58668E-06
3.3653	24.0	9500000.	2.878	0.038360	0.013329	0.20245E-06
3.3653	24.0	6000000.	2.889	0.038060	0.013172	0.12687E-06
3.3653	24.0	16000000.	2.868	0.036307	0.012657	0.32273E-06
3.3653	24.0	3000000.	2.907	0.037947	0.013053	0.63245E-07
3.3653	24.0	300000.	2.952	0.023151	0.007842	0.38585E-08
3.3653	24.0	1000000.	2.928	0.032768	0.011191	0.18205E-07
3.3653	24.0	100000.	2.973	0.015012	0.005049	0.83403E-09
3.3653	24.0	50000.	2.951	0.011321	0.003837	0.31447E-09
3.3653	24.0	20000.	2.979	0.007393	0.002482	0.82140E-10
3.3653	24.0	10000.	2.987	0.005536	0.001853	0.30754E-10
3.3653	24.0	5000.	2.987	0.004109	0.001376	0.11414E-10
3.3653	24.0	2000.	2.982	0.003129	0.001049	0.34762E-11
3.3653	24.0	1000.	2.985	0.002618	0.000877	0.14544E-11
3.3653	24.0	500.	2.987	0.002519	0.000843	0.69976E-12
3.3653	24.0	500.	2.989	0.002411	0.000806	0.66963E-12
3.3653	24.0	200.	2.983	0.001958	0.000656	0.21751E-12
3.3653	24.0	100.	2.988	0.001946	0.000651	0.10814E-12
3.3653	24.0	100.	2.989	0.001831	0.000612	0.10170E-12
3.3653	24.0	50.	2.988	0.001829	0.000612	0.50805E-13
3.3653	24.0	20.	2.990	0.002070	0.000692	0.23000E-13

Naphthalene C₁₀H₈

MIT Material. Science

	Freq., GHz	1	1.7	3	8.5	14
23°C solid	K				2.76	2.75
	D.F.				.00016	.00025
82°C liquid	K	2.53	2.53	2.53		2.47
	D.F.	.0001	.00022	.00052		.00115

Laminated polypropylene

24 GHz 24°C

MIT, Lincoln

Thickness, cm	K	D.F.
.415	2.27	.0010
.751	2.28	.0016
.866	2.27	.0037

RX-18 polymethylpentene

Mitsui
Samples from Naval Underwater Sys. Cen

Color	Freq., MHz	400	1000	3000	8515	21°C
None, 1977	K	2.132	2.130	2.127	2.125	
	D.F.	.00041	.00041	.00043	.00054	
None, 1978	K				2.133	
	D.F.				.00063	
Yellow	K				2.132	
	D.F.				.00062	
Red	K				2.1325	
	D.F.				.00062	
Dark Blue	K				2.134	
	D.F.				.00064	
Light Blue	K				2.130	
	D.F.				.00063	

TPX Natural

Mitsui

T°C	Freq., GHz	1	1.685	2.45	3	5	8.5
25	K	2.122	2.122	2.121	2.121	2.120	2.120
	D.F.	.00059	.00061	.00063	.00063	.00061	.000595
75	K			2.092			
	D.F.			.00067			
125	K			2.060			
	D.F.			.00071			
175	K			2.024			
	D.F.			.00076			

"Texin" 355D, natural, polyurethane

Mobay Chemical Corp.

Oven Dry						
1000/T	T, DEG.C	FREQ., Hz	K1	K2	TAN DELTA	SIGMA, MHO/CM
3.3653	24.0	5.	5.827	0.493223	0.084651	0.13701E-11
3.3653	24.0	10.	5.720	0.321775	0.056253	0.17876E-11
3.3653	24.0	20.	5.624	0.233114	0.041447	0.25902E-11
3.3653	24.0	50.	5.562	0.177018	0.031828	0.49172E-11
3.3653	24.0	100.	5.498	0.158494	0.028829	0.88052E-11
3.3653	24.0	200.	5.466	0.172873	0.031628	0.19208E-10
3.3653	24.0	500.	5.325	0.170832	0.032080	0.47453E-10
3.3653	24.0	1000.	5.258	0.170086	0.032350	0.94492E-10
3.3653	24.0	2000.	5.204	0.169613	0.032595	0.18846E-09
3.3653	24.0	5000.	5.106	0.174394	0.034156	0.48443E-09
3.3653	24.0	10000.	5.026	0.169712	0.033764	0.94284E-09
3.3653	24.0	20000.	4.951	0.186249	0.037615	0.20694E-08
3.3653	24.0	50000.	4.892	0.197352	0.040345	0.54820E-08
3.3653	24.0	100000.	4.765	0.207658	0.043581	0.11537E-07
3.3653	24.0	1000000.	4.446	0.248577	0.055915	0.13810E-06
3.3653	24.0	300000.	4.624	0.223435	0.048325	0.37239E-07
3.3653	24.0	3000000.	4.238	0.261347	0.061662	0.43558E-06
3.3653	24.0	9500000.	4.059	0.285754	0.070401	0.15081E-05
3.3653	24.0	30000000.	3.825	0.329739	0.086210	0.54957E-05

"Texin" 355D**.24% water****Mobay**

1000/T	T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	1000.	5.529	0.197005	0.035632	0.10945E-09
3.3653	24.0	300.	5.653	0.199805	0.035343	0.33301E-10
3.3653	24.0	100.	5.821	0.226719	0.038952	0.12595E-10
3.2653	24.0	3000.	5.409	0.200310	0.037031	0.33385E-09
3.3653	24.0	10000.	5.252	0.209153	0.039825	0.11620E-08
3.3653	24.0	20000.	5.157	0.215246	0.041739	0.23916E-08
3.3653	24.0	50000.	5.041	0.235391	0.046699	0.65386E-08
3.3653	24.0	100000.	4.946	0.236061	0.047723	0.13114E-07
3.3653	24.0	1000000.	4.569	0.270618	0.059230	0.15034E-06
3.3653	24.0	300000.	4.771	0.249592	0.052311	0.41599E-07
3.3653	24.0	3000000.	4.354	0.278557	0.063980	0.46426E-06
3.3653	24.0	9500000.	4.159	0.298530	0.071771	0.15756E-05
3.3653	24.0	100.	5.744	0.198500	0.034555	0.11028E-10
3.3653	24.0	50.	5.865	0.240356	0.040982	0.66766E-11
3.3653	24.0	20.	5.990	0.358001	0.059769	0.39778E-11
3.3653	24.0	10.	6.088	0.432141	0.070988	0.24008E-11

"Texin" 355D**1.14% water****Mobay**

1000/T	T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	30000000.	4.044	0.396381	0.098006	0.66063E-05
3.3653	24.0	9500000.	4.328	0.378195	0.087390	0.19960E-05
3.3653	24.0	6000000.	4.471	0.369416	0.082618	0.12314E-05
3.3653	24.0	3000000.	4.603	0.359783	0.078168	0.59964E-06
3.3653	24.0	400000.	5.151	0.317665	0.061671	0.70592E-07
3.3653	24.0	200000.	5.151	0.292836	0.056847	0.32537E-07
3.3653	24.0	100000.	5.708	0.280082	0.049068	0.15560E-07
3.3653	24.0	50000.	5.379	0.261052	0.048534	0.72515E-08
3.3653	24.0	20000.	5.573	0.244764	0.043922	0.27136E-08
3.3653	24.0	10000.	5.673	0.239800	0.042267	0.13322E-08
3.3653	24.0	5000.	6.185	0.242461	0.039204	0.87350E-09
3.3653	24.0	2000.	5.883	0.272124	0.046255	0.30236E-09
3.3653	24.0	1000.	5.964	0.325954	0.054652	0.18109E-09
3.3653	24.0	500.	6.095	0.425658	0.069834	0.11824E-09
3.3653	24.0	200.	6.246	0.691620	0.110727	0.76847E-10
3.3653	24.0	100.	6.407	1.150263	0.179529	0.63903E-10
3.3653	24.0	1000000.	4.987	0.346178	0.070842	0.19232E-06
3.3653	24.0	50.	6.660	1.667348	0.250363	0.46315E-10
3.3653	24.0	50.	6.640	1.947284	0.293261	0.54091E-10
3.3653	24.0	20.	7.157	4.148470	0.579605	0.46094E-10
3.3653	24.0	10.	7.834	7.581223	0.967773	0.42118E-10

Polysulfone board**Norplex Division, UOP Inc.**

T°C	Freq., Hz	1	2.45	3	5	8.5	14	24
23	tan A	2.981	2.978	2.977	2.975	2.967	2.950	2.945
		.00393	.00459	.00469	.00524	.00539	.00560	.00573
51	tan A	2.983	2.976	2.975	2.973	2.954	2.944	2.940
		.00412	.00484	.00523	.00568	.00595	.00623	.00649
100	tan A	2.984	2.982	2.980	2.976	2.953	2.943	2.930
		.00458	.00548	.00585	.00634	.00704	.00734	.00760
150	tan A	2.965	2.963	2.961	2.958	2.948	2.943	2.935
		.99428	.00552	.00603	.00664	.00766	.00812	.00877
175	tan A	2.948	2.946	2.945	2.941	2.934	2.928	2.921
		.00370	.00500	.00546	.00623	.00762	.00872	.00948
150	tan A	2.952	2.952	2.951	2.950	2.946	2.940	2.934
		.00362	.00474	.00526	.00594	.00695	.00725	.00784
100	tan A	2.951	2.952	2.951	2.949	2.942	2.936	2.931
		.00357	.00458	.00489	.00547	.00629	.00660	.00680
50	tan A	2.959	2.957	2.957	2.955	2.940	2.935	2.928
		.00352	.03431	.00456	.00501	.00562	.00570	.00574
23	tan A	2.959	2.958	2.956	2.954	2.937	2.935	2.930
		.00321	.00498	.00419	.00467	.00524	.00518	.00510

Temperature Runs to the Liquid State at 2.45 Ghz on ten materials
 Phillips Petroleum Co.

#52263

Type R-4 glass filled
 polyphenylene sulfide

T°C	K	D.F.	Thick.,cm
24.5	4.12	.00438	1.506
47	4.11	.00464	1.510
85	4.10	.00505	1.517
112	4.05	.0057	1.523
155	4.04	.0083	1.528
205	4.00	.0106	1.545
242	3.95	.0128	1.591

#52264

Type R-8 Glass and mineral filled
 polyphenylene sulfide

T°C	K	D.F.	Thick.,cm
24	4.33	.0059	1.574
64	4.35	.0088	1.579
92	4.38	.0112	1.578
112	4.34	.0126	1.579
143	4.29	.0132	1.590
178	4.26	.0134	1.599
209	4.11	.0134	1.654
229	3.97	.0128	1.732

#52265

Type R-10 glass & mineral filled
 polyphenylene sulfide color cmpd.

22	4.88	.0037	1.513
55	4.89	.0040	1.517
76	4.90	.0042	1.519
99	4.92	.00514	1.522
118	4.91	.0059	1.521
152	4.90	.0076	1.528
171	4.90	.00816	1.531
210	4.88	.00936	1.547
240	4.83	.0105	1.573

#52266

Mineral filled polysulfone

23	3.37	.00517	1.670
67	3.38	.00595	1.676
93	3.38	.0064	1.680
120.6	3.33	.0062	1.683
153	3.23	.0065	1.709
176.5	2.91	.0097	1.908
206	2.55	.0224	2.377

#52267

polysulfone

23	3.06	.0049	1.678
50.4	3.07	.0055	1.680
89.6	3.04	.0060	1.690
113	3.00	.0057	1.700
157	2.91	.0060	1.735
174	2.62	.0084	1.884
204	2.30	.0209	2.34

#52268

Glass filled polybutylene
 terephthalate

24	3.49	.00645	1.664
54	3.47	.0110	1.676
87	3.47	.0203	1.688
114	3.48	.0352	1.705
145	3.50	.0448	1.726
175	3.65	.0772	1.776
197	3.94	.0937	1.772
235	4.24	.1152	1.818

#52269

Polybutylene terephthalate

21.7	2.97	.0050	1.707
55.4	2.98	.0102	1.721
80.4	2.96	.0189	1.737
118.5	2.96	.0435	1.770
139	2.99	.0596	1.771
165	3.14	.0836	1.768
199	3.58	.1172	1.778
230	3.90	.1383	1.849

#52270

Glass filled polyacetal

21.6	3.26	.0292	1.728
49.5	3.49	.0309	1.761
87	3.61	.0649	1.785
118.5	3.75	.0563	1.799
146	3.99	.0511	1.812
179	4.24	.0491	1.943
199	4.04	.0445	2.098

Phillips plastics, continued

#52271 polyacetal

T°C	K	D.F.	Thick., cm
21	3.08	.0338	1.679
51.4	3.21	.0623	1.685
75	3.39	.0805	1.700
111	3.60	.0741	1.713
142	3.82	.0605	1.728
184	3.99	.0489	1.980
196	4.08	.046	1.755

#52272 polypropylene

T°C	K	D.F.	Thick., cm
24.2	2.242	.00041	1.684
40.3	2.240	.00045	1.684
56	2.233	.00051	1.685
96	2.195	.00054	1.702
130.7	2.159	.00069	1.729
158	2.014	.00079	1.846
187	1.779	.00077	2.559

Cross-linked polyethylene CL-100

Phillips
Sample molded by Hardigg

24 GHz 23°C K = 2.229 D.F. = .00056

Ferrite Absorber Mixes
with Dow Corning 184

2.45 GHz

Raytheon

R-153 Ferrite, 60 wt%,

Q-1 2.5:1 ratio

T°C	K'	tan δ	μ'/μ_0	$\tan \delta_m$	T°C	K'	tan δ	μ'/μ_0	$\tan \delta_m$
22*	4.47	.0127	.9985	.491	22*	5.79	.0129	1.553	.8996
24	4.35	.0123	1.014	.483	23	5.72	.0117	1.554	.894
65	4.27	.0110	.940	.498	62	5.63	.0112	1.502	.881
88	4.20	.0110	.901	.432	92	5.60	.0109	1.397	.903
113	4.15	.0111	.837	.454	95	5.60	.0109	1.386	.902
127	4.12	.0117	.822	.391	120	5.56	.0129	1.323	.911
156	4.09	.0129	.817	.295	128	5.53	.0137	1.309	.902
179	4.05	.0138	.813	.232	153	5.50	.0150	1.211	.924
210	4.00	.0152	.840	.1535	184	5.46	.0159	1.130	.926
241	3.95	.0180	.891	.052	220	5.41	.0195	1.027	.941
259	3.92	.0190	.913	.033	239	5.37	.0214	1.012	.944
290	3.87	.0212	.984	.0081	272	5.33	.0265	.896	.944
22	4.37	.0114	1.012	.494	298	5.30	.0285	.797	1.060
					21.7	5.90	.0127	1.480	.997

* in room temp. sample holder, other values in high temp. holder

"Plexiglass" V811-100, polymethylmethacrylate, oven dry Rhom & Haas Co.

1000/T	T, DEG.C	FREQ., Hz	K1	K2	TAN DELTA	SIGMA, MHO/CM
3.3653	24.0	30000000.	2.607	0.025432	0.009755	0.42386E-06
3.3653	24.0	9500000.	2.596	0.015776	0.006078	0.83264E-07
3.3653	24.0	3000000.	2.639	0.035585	0.013484	0.59308E-07
3.3653	24.0	300000.	2.681	0.051897	0.019354	0.86496E-08
3.3653	24.0	1000000.	2.684	0.040346	0.015143	0.22415E-07
3.3653	24.0	100000.	2.705	0.067965	0.021432	0.32203E-08
3.3653	24.0	50000.	2.742	0.067078	0.024462	0.18633E-08
3.3653	24.0	20000.	2.782	0.076921	0.027652	0.85468E-09
3.3653	24.0	10000.	2.849	0.082731	0.029037	0.45962E-09
3.3653	24.0	10000.	2.849	0.084718	0.029735	0.47065E-09
3.3653	24.0	5000.	2.889	0.096873	0.033535	0.26909E-09
3.3653	24.0	3000.	2.921	0.105489	0.036117	0.17582E-09
3.3653	24.0	1000.	3.000	0.127622	0.042641	0.70901E-10
3.3653	24.0	500.	3.032	0.142581	0.047028	0.39606E-10
3.3653	24.0	200.	3.100	0.159903	0.051582	0.17767E-10
3.3653	24.0	100.	3.168	0.147102	0.046427	0.81723E-11
3.3653	24.0	50.	3.255	0.157021	0.048238	0.43617E-11
3.3653	24.0	20.	3.408	0.165988	0.049002	0.16554E-11
3.3653	24.0	10.	3.494	0.172459	0.049503	0.96088E-12
3.3653	24.0	5.	3.569	0.174577	0.048921	0.48494E-12
3.3653	24.0	3.	3.636	0.138368	0.038050	0.23061E-12
3.3653	24.0	2.	3.731	0.143764	0.038530	0.13974E-12

"Plexiglass" continued

Rhom & Haas

.27% water Molded by Eastman, from MIT ME

1000/T	T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	9500000.	2.596	0.034817	0.013414	0.18376E-06
3.3653	24.0	3000000.	2.654	0.041893	0.015783	0.69822E-07
3.3653	24.0	300000.	2.731	0.059684	0.021858	0.99473E-08
3.3653	24.0	1000000.	2.673	0.050151	0.018762	0.27862E-07
3.3653	24.0	1000000.	2.755	0.067682	0.024506	0.37601E-08
3.3653	24.0	50000.	2.799	0.072824	0.026018	0.20229E-08
3.3653	24.0	20000.	2.843	0.079186	0.027854	0.87984E-09
3.3653	24.0	10000.	2.844	0.085537	0.030081	0.47520E-09
3.3653	24.0	3000.	2.910	0.103130	0.035441	0.17108E-09
3.3653	24.0	1000.	3.014	0.122055	0.040498	0.67808E-10
3.3653	24.0	1000.	3.014	0.121073	0.040165	0.67263E-10
3.3653	24.0	300.	3.001	0.143380	0.046533	0.23897E-10
3.3653	24.0	100.	3.224	0.171322	0.053137	0.95179E-11
3.3653	24.0	50.	3.289	0.150950	0.045894	0.41931E-11
3.3653	24.0	20.	3.407	0.161970	0.047547	0.17997E-11
3.3653	24.0	10.	3.539	0.172468	0.048727	0.95815E-12
3.3653	24.0	5.	3.632	0.172526	0.047507	0.47924E-12
3.3653	24.0	3.	3.658	0.147920	0.040435	0.27390E-12
3.3653	24.0	2.	3.797	0.140221	0.036928	0.15580E-12

1.5% water

1000/T	T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3653	24.0	10.	4.117	0.241926	0.058758	0.13440E-11
3.3653	24.0	10.	4.147	0.222634	0.053684	0.12369E-11
3.3653	24.0	20.	4.029	0.218649	0.054270	0.24294E-11
3.3653	24.0	50.	3.871	0.206526	0.053346	0.57368E-11
3.3653	24.0	100.	3.768	0.194061	0.051509	0.10781E-10
3.3653	24.0	200.	3.672	0.178341	0.048587	0.19816E-10
3.3653	24.0	500.	3.532	0.187601	0.053107	0.52111E-10
3.3653	24.0	1000.	3.454	0.169185	0.048989	0.93992E-10
3.3653	24.0	2000.	3.421	0.149799	0.043781	0.16644E-09
3.3653	24.0	5000.	3.341	0.129041	0.038624	0.35045E-09
3.3653	24.0	10000.	3.290	0.116235	0.035327	0.64575E-09
3.3653	24.0	20000.	3.243	0.107560	0.033162	0.11951E-08
3.3653	24.0	50000.	3.191	0.098730	0.030953	0.27439E-08
3.3653	24.0	100000.	3.162	0.095400	0.030169	0.53000E-08
3.3653	24.0	500000.	3.058	0.085860	0.027987	0.23850E-07
3.3653	24.0	1000000.	3.029	0.078446	0.025898	0.43581E-07
3.3653	24.0	3000000.	3.095	0.088521	0.028603	0.14754E-07
3.3653	24.0	9500000.	2.976	0.068226	0.022924	0.11371E-06
3.3653	24.0	30000000.	2.935	0.056405	0.019220	0.29769E-06
3.3653	24.0	30000000.	2.874	0.046728	0.016257	0.77880E-06

Richo 31001 polyurethane

Richo Plastics

Sample from Sperry

8.5 GHz 23°C K = 2.979 D.F. = .0186

"Duroid" 5650 M-5

Rogers

8.5 GHz 21 °C

E perpendicular hot pressing direction K = 2.660 D.F. = .00242

E parallel " " " K = 2.558 D.F. = .00206

"Duroid" 5870

Rogers

8.5 GHz 21 °C E parallel to sheet

Thickness, inch K D.F.

1/16	2.42	.0019
.010	2.33	.0019

"Duroid" 5870M-1

Rogers

E perpendicular HPD 2.443 .00207

E parallel HPD 2.317 .00138

"Duroid" 5870M

Rogers

In Room Temperature Sample Holder

		Rotation (degrees)	K	$\tan \delta$		
1 pc. full thickness	Face 1	0	2.630	.00287	E \perp	
		90	2.495	.00237	E //	
	2	0	2.632	.0031	E \perp	
		90	2.484	.00207	E //	
pc. 1 / pc. 2		0	2.592	.00283	E \perp	
		90	2.452	.00213	E //	

Temperature run pc. 2/pc. 1

T°C	E \perp K	$\tan \delta$	Thickness (cm)	E // K	$\tan \delta$
23.1	2.594	.00287	1.8583	2.462	.00256
50	2.592	.00306	1.8619	2.464	.00226
97	2.593	.00229	1.8670	2.460	.00203
160.	2.591	.00209	1.8681	2.452	.00199
205	2.577	.00159	1.8722	2.425	.00129
246	2.571	.00182	1.8734	2.419	.00131
300	2.563	.00186	1.8805	2.405	.00131
350	2.395	.00239	2.0639	2.258	.00130
395	2.242	.00251	2.2581	2.159	.00100
468	2.088	.00289	2.5177	1.989	.00112
504	1.828	.00396	3.2300	1.722	.00339
528	1.095	.00155	4.7506	1.017	.0195

Polybutylenes

Shell

		Room Temperature			
Material #	Freq., GHz	.4	1	3	8.5
0200	K	2.265	2.265	2.264	2.264
	D.F.	.00029	.00026	.00025	.000275
8240	K	2.247	2.247	2.246	2.246
	D.F.	.00029	.00029	.00029	.00027

"Epon" 828

100 pts resin, 80 pts hardener, 1 pt accelerator
(ATC-3)

Shell
Sample from Brunswick

	2.45 GHz 23°C	K	D.F.
Sample #1, 30 min. after mixing, some bubbles		3.873	.198
5 hrs at 23°C, no bubbles		3.907	.214
47 hrs " " "		3.710	.152
Then 95 hrs at 40°C		3.310	.0756
Then 80 hrs at 60°C		3.165	.0533
Sample #2 Cured 1 hour at 105°C		3.14	.054

Various Plastics

Samples formed by Sperry

	All at 8.5 GHz, R.T.	K	tan δ
Cycloaliphatic resin		2.850	.0209
Polyester, cutting, face 1		2.861	.010
face 2		2.850	.0086
", Laminac		2.911	.0128
"Epon" 815, clear		2.60	.0074
white		13.9	.007
Ciba 2790, clear		2.87	.0135
HY 917		12.9	.0095
Dec. 7521		13.0	.0045
Hetron 92FS		13.5	.0095
"Stafoam"		1.035	.00103
Richo 90-578 + 34-841		1.042	.00073
Rigid polyurethane foam		1.036	.00055
(Same at 1 GHz)		1.039	.00060

Rigid polyurethane foams:

Sample Designation	Length, cm	K	D.F.	gm/cm ³ (K-1)/den.
V6	2.35	1.1224	.00145	- -
	3.55	1.1225	.00155	.096 1.28
V8	2.10	1.1580	.00214	- -
	3.12	1.1591	.00229	.1189 1.34
V12	2.30	1.2872	.00390	- -
	3.37	1.2906	.00362	.2056 1.41
V16	2.32	1.3271	.00456	- -
	3.45	1.3252	.00460	.2398 1.35
V20	2.13	1.3948	.00455	- -
	3.21	1.3895	.00445	.2941 1.32

"Tellite" RCP

Tellite

8.5 GHz R.T.

Thickness, inch	K	D.F.
1/32	2.35	.0004
1/16	2.34	.00033

"Mindel" Stabilized basic polysulfone 1976 Union Carbide Corp.

1000/T	T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3484	25.5	1000000.	3.607	0.013891	0.003851	0.77170E-08
3.3484	25.5	9500000.	3.584	0.014416	0.004022	0.76082E-07
3.3484	25.5	30000000.	3.579			
3.3484	25.5	100000.	3.627	0.008946	0.002466	0.49697E-09
3.3484	25.5	10000.	3.639	0.008157	0.002242	0.45315E-10
3.3484	25.5	1000.	3.651	0.010085	0.002762	0.56027E-11
3.3484	25.5	100.	3.671	0.012933	0.003523	0.71852E-12
3.3484	25.5	50.	3.683	0.014043	0.003813	0.39008E-12
3.0945	50.0	50.	3.626	0.019363	0.005340	0.53787E-12
3.0945	50.0	100.	3.614	0.016199	0.004482	0.89995E-12
3.0945	50.0	1000.	3.590	0.011298	0.003147	0.62767E-11
3.0945	50.0	10000.	3.572	0.008738	0.002446	0.48544E-10
3.0945	50.0	100000.	3.558	0.007548	0.002121	0.41932E-09
3.0945	50.0	1000000.	3.538	0.010719	0.003030	0.59551E-08
3.0945	50.0	9500000.	3.520	0.013302	0.003779	0.70207E-07
3.0945	50.0	30000000.	3.512			
2.6799	100.0	30000000.	3.387			
2.6799	100.0	9500000.	3.390	0.009495	0.002801	0.50114E-07
2.6799	100.0	1000000.	3.425	0.006362	0.001858	0.35345E-08
2.6799	100.0	100000.	3.431	0.006911	0.002014	0.38395E-09
2.6799	100.0	10000.	3.441	0.009793	0.002843	0.54349E-10
2.6799	100.0	1000.	3.461	0.015383	0.004444	0.85459E-11
2.6799	100.0	100.	3.510	0.025626	0.007301	0.14237E-11
2.6799	100.0	50.	3.528	0.030249	0.008574	0.84025E-12
2.3632	150.0	50.	3.557	0.046422	0.013050	0.12895E-11
2.3632	150.0	100.	3.550	0.037887	0.010671	0.21049E-11
2.3632	150.0	1000.	3.504	0.022269	0.006356	0.12372E-10
2.3632	150.0	10000.	3.497	0.013270	0.003795	0.73723E-10
2.3632	150.0	100000.	3.458	0.008736	0.002526	0.48531E-09
2.3632	150.0	1000000.	3.456	0.005919	0.001712	0.32885E-08
2.3632	150.0	9500000.	3.436	0.006981	0.002032	0.36846E-07
2.3632	150.0	30000000.	3.424			
2.2314	175.0	30000000.	3.434			
2.2314	175.0	9500000.	3.444	0.006878	0.001997	0.36303E-07
2.2314	175.0	1000000.	3.458	0.007112	0.002056	0.39510E-08
2.2314	175.0	100000.	3.480	0.009930	0.002854	0.55169E-09
2.2314	175.0	10000.	3.492	0.016847	0.004825	0.93595E-10
2.2314	175.0	1000.	3.522	0.027321	0.007758	0.15178E-10
2.2314	175.0	100.	3.570	0.054329	0.015217	0.30183E-11
2.2314	175.0	50.	3.596	0.076612	0.021303	0.21281E-11

At 25°C after temperature run:

Freq., MHz	.5	1	2	3.5	6	9.5
Tan delta	.00336	.00370	.00369	.00350	.00339	.00326

Microwave data:

Freq., GHz	.15	.3	1	2.45	3	8.5
K	3.63	3.63	3.63	3.626	3.624	3.618
Tan delta	.00300	.00320	.00362	.00405	.00414	.00477

"Radel" polyphenylsulfone

1976

Union Carbide

1000/T	T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3428	26.0	1000000.	3.090	0.015613	0.005053	0.86739E-08
3.3428	26.0	9500000.	3.067	0.013474	0.004393	0.71113E-07
3.3428	26.0	30000000.	3.054	0.011929	0.003906	0.19881E-06
3.3428	26.0	100.	3.138	0.003346	0.001056	0.18588E-12
3.3428	26.0	50.	3.138	0.003189	0.001018	0.10630E-12
3.3428	26.0	50.	3.139	0.003530	0.001124	0.98045E-13
3.3428	26.0	1000.	3.130	0.0033654	0.001167	0.20299E-11
3.3428	26.0	10000.	3.119	0.004941	0.001584	0.27451E-10
3.3428	26.0	100000.	3.111	0.009492	0.003051	0.52733E-09
3.0945	50.0	30000000.	3.034	0.016283	0.005366	0.27139E-08
3.0945	50.0	9500000.	3.056	0.014325	0.004687	0.75605E-07
3.0945	50.0	1000000.	3.070	0.012026	0.003917	0.66812E-08
3.0945	50.0	100000.	3.082	0.006360	0.002161	0.37002E-09
3.0945	50.0	10000.	3.088	0.004375	0.001417	0.24303E-10
3.0945	50.0	1000.	3.092	0.003760	0.001216	0.20886E-11
3.0945	50.0	100.	3.114	0.003895	0.001251	0.21641E-12
3.0945	50.0	50.	3.116	0.004514	0.001449	0.12538E-12
2.6799	100.0	50.	3.069	0.010899	0.003551	0.30274E-12
2.6799	100.0	100.	3.063	0.008544	0.002789	0.47466E-12
2.6799	100.0	1000.	3.064	0.004451	0.001453	0.24730E-11
2.6799	100.0	10000.	3.060	0.003849	0.001258	0.21385E-10
2.6799	100.0	100000.	3.032	0.004239	0.001398	0.23549E-09
2.6799	100.0	1000000.	3.025	0.006789	0.002244	0.37714E-08
2.6799	100.0	9500000.	3.022	0.011622	0.003346	0.61341E-07
2.6799	100.0	30000000.	2.986	0.014829	0.004967	0.24715E-06
2.3632	150.0	30000000.	2.997	0.011814	0.003943	0.19691E-06
2.3632	150.0	9500000.	3.003	0.008740	0.002910	0.46126E-07
2.3632	150.0	1000000.	3.002	0.005359	0.001785	0.29770E-08
2.3632	150.0	100000.	2.985	0.004182	0.001401	0.23236E-09
2.3632	150.0	10000.	3.008	0.004254	0.001414	0.23634E-10
2.3632	150.0	1000.	3.017	0.006471	0.002145	0.35949E-11
2.3632	150.0	100.	3.030	0.017789	0.005871	0.98825E-12
2.3632	150.0	50.	3.027	0.029222	0.009655	0.81172E-12
2.2314	175.0	1000.	2.996	0.010348	0.003454	0.57488E-11
2.2314	175.0	10000.	2.989	0.005184	0.001734	0.28802E-10
2.2314	175.0	100000.	2.985	0.004093	0.001371	0.22737E-09
2.2314	175.0	1000000.	2.983	0.004754	0.001594	0.26410E-08
2.2314	175.0	9500000.	2.981	0.007016	0.002354	0.37027E-07
2.2314	175.0	30000000.	2.959	0.009583	0.003239	0.15972E-06
2.2314	175.0	100.	3.001	0.047240	0.015739	0.26245E-11
2.2314	175.0	50.	3.016	0.078053	0.025882	0.21681E-11

At 25°C after temperature run:

Freq., MHz	.1	.5	1	2	3.5	6	9.5	16
Tan delta	.00355	.00502	.00539	.00562	.00553	.00513	.00489	.00446

Microwave data, as received, 26°C:

Freq., GHz	.15	.3	1	2.45	3	8.5
K	3.15	3.15	3.15	3.145	3.14	3.13
Tan delta	.00422	.00466	.00535	.00583	.00590	.00637

"Radel" 5000, batch 6

1977

Union Carbide

1000/T	T, DEG.C	FREQ., HZ	K1	K2	TAN DELTA	SIGMA,MHO/CM
3.3462	25.7	30000000.	3.225	0.015655	0.004855	0.26091E-06
3.3462	25.7	9500000.	3.249	0.017758	0.005468	0.93720E-07
3.3462	25.7	1000000.	3.280	0.019903	0.006068	0.11057E-07
3.3462	25.7	500000.	3.289	0.016275	0.005556	0.50765E-08
3.3462	25.7	3500000.	3.273	0.019114	0.005840	0.37166E-07
3.3462	25.7	6000000.	3.267	0.018102	0.005540	0.60341E-07
3.3462	25.7	2000000.	3.278	0.020383	0.006217	0.22647E-07
3.3462	25.7	100000.	3.314	0.012325	0.003719	0.68470E-09
3.3462	25.7	10000.	3.324	0.006728	0.002024	0.37377E-10
3.3462	25.7	1000.	3.333	0.005138	0.001542	0.28547E-11
3.3462	25.7	100.	3.337	0.004497	0.001347	0.24983E-12
3.3462	25.7	50.	3.340	0.004390	0.001315	0.12194E-12
3.3462	25.7	10.	3.344	0.004597	0.001375	0.25536E-13
3.0945	50.0	10.	3.373	0.003845	0.001140	0.21362E-13
3.0945	50.0	50.	3.367	0.004292	0.001275	0.11922E-12
3.0945	50.0	100.	3.365	0.004294	0.001276	0.23854E-12
3.0945	50.0	1000.	3.365	0.004493	0.001335	0.24961E-11
3.0945	50.0	10000.	3.361	0.005586	0.001662	0.31031E-10
3.0945	50.0	100000.	3.349	0.008392	0.002506	0.46620E-09
3.0945	50.0	3500000.	3.330	0.016008	0.004808	0.88935E-08
3.0945	50.0	6000000.	3.308	0.018926	0.005720	0.36800E-07
3.0945	50.0	9500000.	3.257	0.019724	0.006056	0.10410E-06
3.0945	50.0	30000000.	3.230	0.017414	0.005391	0.29023E-06
2.6799	100.0	30000000.	3.277	0.017188	0.005246	0.28647E-06
2.6799	100.0	9500000.	3.303	0.016053	0.004861	0.84724E-07
2.6799	100.0	6000000.	3.312	0.014460	0.004366	0.48201E-07
2.6799	100.0	3500000.	3.316	0.013026	0.003928	0.25327E-07
2.6799	100.0	1000000.	3.322	0.009055	0.002726	0.50305E-08
2.6799	100.0	100000.	3.329	0.005697	0.001711	0.31651E-09
2.6799	100.0	10000.	3.344	0.004510	0.001349	0.25054E-10
2.6799	100.0	1000.	3.346	0.003191	0.000954	0.17728E-11
2.6799	100.0	100.	3.346	0.004024	0.001202	0.22355E-12
2.6799	100.0	50.	3.348	0.004350	0.001299	0.12082E-12
2.3632	150.0	10.	3.352	0.004761	0.001421	0.26432E-13
2.3632	150.0	50.	3.337	0.008127	0.002436	0.45151E-13
2.3632	150.0	100.	3.326	0.005039	0.001515	0.13997E-12
2.3632	150.0	1000.	3.325	0.004616	0.001388	0.25643E-12
2.3632	150.0	10000.	3.324	0.004200	0.001264	0.23331E-11
2.3632	150.0	100000.	3.318	0.005729	0.001726	0.31828E-10
2.3632	150.0	1000000.	3.312	0.004871	0.001471	0.27064E-09
2.3632	150.0	10000000.	3.299	0.008096	0.002454	0.44980E-08
2.3632	150.0	9500000.	3.304	0.012436	0.003764	0.65635E-07
2.3632	150.0	30000000.	3.235	0.018230	0.005016	0.27050E-06
2.1135	200.0	30000000.	3.204	0.017966	0.005608	0.29944E-06
2.1135	200.0	9500000.	3.259	0.013099	0.004019	0.69133E-07
2.1135	200.0	1000000.	3.257	0.008395	0.002578	0.46642E-08
2.1135	200.0	100000.	3.274	0.011336	0.003463	0.62976E-09
2.1135	200.0	10000.	3.292	0.006291	0.001911	0.34950E-10
2.1135	200.0	1000.	3.312	0.007955	0.002402	0.44192E-11
2.1135	200.0	50.	3.314	0.022555	0.006806	0.12530E-11
2.1135	200.0	10.	3.318	0.037448	0.011285	0.10402E-11
2.0074	225.0	10.	3.335	0.129655	0.038878	0.72030E-12
2.0074	225.0	50.	4.254	1.648727	0.387569	0.91596E-11
2.0074	225.0	100.	3.708	0.455797	0.122933	0.12661E-10
2.0074	225.0	1000.	3.579	0.345433	0.096506	0.19191E-10
2.0074	225.0	10000.	3.401	0.104960	0.030863	0.58311E-10
2.0074	225.0	10000.	3.312	0.044307	0.013377	0.24615E-09
2.0074	225.0	100000.	3.268	0.021754	0.006656	0.12085E-08
2.0074	225.0	1000000.	3.240	0.017423	0.005378	0.96792E-08
2.0074	225.0	9500000.	3.202	0.018617	0.005815	0.98257E-07
2.0074	225.0	30000000.	3.148	0.019601	0.006226	0.32668E-06

"Radel" 5000, continued

T°C	Freq.,GHz	1	1.685	2.45	3	5	8.515
25	K	3.195	3.190	3.186	3.182	3.170	3.155
	D.F.	.00547	.00533	.00594	.00618	.00646	.00654
75	K	3.200	3.193	3.187	3.183	3.171	3.157
	D.F.	.0065	.00646	.0067	.0074	.0080	.00757
125	K	3.197	3.191	3.182	3.178	3.169	3.155
	D.F.	.0074	.0072	.0077	.0086	.0094	.00875
175	K	3.194	3.190	3.181	3.177	3.166	3.141
	D.F.	.00805	.00795	.00835	.0092	.010	.0098
200	K	3.199	3.193	3.180	3.175	3.161	3.120
	D.F.	.0084	.0083	.0088	.0096	.0103	.0102

"Udell" P1700, Blend 63-72

1977

Union Carbide

1000/T	T, DEG.C	FREQ.,HZ	K1	K2	TAN DELTA	SIGMA, MHO/CM
3.3653	24.0	10.	3.157	0.003836	0.001215	0.21313E-13
3.3653	24.0	50.	3.154	0.003579	0.001135	0.99417E-13
3.3653	24.0	100.	3.153	0.003723	0.001181	0.20683E-12
3.3653	24.0	100.	3.153	0.003624	0.001149	0.20131E-12
3.3653	24.0	1000.	3.139	0.004013	0.001279	0.22296E-11
3.3653	24.0	10000.	3.129	0.005502	0.001759	0.30567E-10
3.3653	24.0	100000.	3.119	0.010105	0.003240	0.56139E-09
3.3653	24.0	1000000.	3.095	0.015610	0.005543	0.86721E-08
3.3653	24.0	9500000.	3.080	0.015480	0.00525	0.81701E-07
3.3653	24.0	30000000.	3.070	0.009535	0.00306	0.15892E-06
3.0945	50.0	30000000.	3.076	0.009711	0.00357	0.16185E-06
3.0945	50.0	9500000.	3.085	0.015347	0.004975	0.80997E-07
3.0945	50.0	10000000.	3.096	0.011903	0.003144	0.66125E-08
3.0945	50.0	1000000.	3.102	0.005793	0.001668	0.32186E-09
3.0945	50.0	10000.	3.109	0.003908	0.00157	0.21711E-10
3.0945	50.0	1000.	3.116	0.002879	0.000124	0.15996E-11
3.0945	50.0	100.	3.123	0.002834	0.000307	0.15742E-12
3.0945	50.0	50.	3.126	0.002814	0.000300	0.78171E-13
3.0945	50.0	10.	3.127	0.002999	0.000059	0.16659E-13
2.6799	100.0	10.	3.116	0.005021	0.001611	0.27895E-13
2.6799	100.0	50.	3.110	0.003440	0.001706	0.95564E-13
2.6799	100.0	100.	3.108	0.003318	0.001668	0.18434E-12
2.6799	100.0	1000.	3.103	0.000283	0.000091	0.15746E-12
2.6799	100.0	10000.	3.098	0.003210	0.001046	0.17633E-10
2.6799	100.0	100000.	3.093	0.004087	0.00132	0.22706E-09
2.6799	100.0	1000000.	3.084	0.006812	0.002209	0.37843E-08
2.6799	100.0	9500000.	3.076	0.015220	0.004948	0.30328E-07
2.6799	100.0	30000000.	3.064	0.014844	0.004844	0.24740E-06
2.3632	150.0	30000000.	3.065	0.007800	0.002545	0.13000E-06
2.3632	150.0	9500000.	3.070	0.009555	0.003113	0.50491E-07
2.3632	150.0	1000000.	3.078	0.005506	0.001789	0.30586E-08
2.3632	150.0	100000.	3.085	0.003295	0.001068	0.18304E-09
2.3632	150.0	10000.	3.089	0.003178	0.001029	0.17657E-10
2.3632	150.0	1000.	3.092	0.003490	0.001129	0.19390E-11
2.3632	150.0	100.	3.105	0.004438	0.001430	0.24657E-12
2.3632	150.0	50.	3.121	0.005444	0.001756	0.15121E-12
2.3632	150.0	10.	3.107	0.008402	0.002704	0.46679E-13
2.2314	175.0	10.	3.123	0.024379	0.007807	0.13544E-12
2.2314	175.0	50.	3.113	0.012030	0.003865	0.33417E-12
2.2314	175.0	100.	3.097	0.010603	0.003424	0.58908E-12
2.2314	175.0	1000.	3.089	0.004452	0.001441	0.24735E-11
2.2314	175.0	10000.	3.086	0.005330	0.001727	0.29611E-10
2.2314	175.0	100000.	3.075	0.002816	0.000916	0.15645E-09
2.2314	175.0	1000000.	3.065	0.003813	0.001244	0.21184E-08
2.2314	175.0	9500000.	3.033	0.010316	0.003401	0.54445E-07
2.2314	175.0	30000000.	3.023	0.012438	0.004114	0.20730E-06
2.1135	200.0	30000000.	3.066	0.018076	0.005895	0.30127E-06
2.1135	200.0	9500000.	3.079	0.016358	0.005312	0.86331E-07
2.1135	200.0	1000000.	3.102	0.019015	0.006130	0.10564E-07
2.1135	200.0	100000.	3.132	0.040219	0.012840	0.22344E-08
2.1135	200.0	10000.	3.211	0.105181	0.032752	0.58434E-09
2.1135	200.0	1000.	3.413	0.253232	0.074187	0.14068E-09
2.1135	200.0	100.	3.939	0.517254	0.131319	0.28736E-10
2.1135	200.0	50.	4.216	0.636457	0.150959	0.17679E-10
2.1135	200.0	10.	4.976	0.980310	0.196988	0.54462E-10

"Udell" P1700, continued

T°C	Freq., GHz	1	1.685	2.45	3	5	8.515
25	K	2.995	2.993	2.991	2.990	2.986	2.980
	D.F.	.00435	.0047	.0050	.00515	.0056	.00608
75	K	2.993	2.991	2.988	2.987	2.982	2.976
	D.F.	.00497	.0053	.00495	.00584	.00618	.00661
125	K	2.984	2.983	2.979	2.977	2.973	2.969
	D.F.	.00526	.0056	.00517	.00637	.00676	.00737
175	K	3.003	2.998	2.983	2.974	2.930	2.856
	D.F.	.0080	.0083	.00732	.00902	.0087	.00816

"Udell" P8000 (formerly "Mindel") 1977 Union Carbide

1000/T	T, DEG.C	FREQ., Hz	K1	K2	TAN DELTA	SIGMA, MHO/CM
3.3597	24.5	9500000.	3.650	0.015715	0.004306	0.82939E-07
3.3597	24.5	30000000.	3.620	0.013623	0.003763	0.22705E-06
3.3597	24.5	1000000.	3.680	0.016830	0.004573	0.93498E-08
3.3597	24.5	100000.	3.701	0.011566	0.003125	0.64255E-09
3.3597	24.5	10000.	3.722	0.009637	0.002589	0.53540E-10
3.3597	24.5	1000.	3.735	0.012112	0.003242	0.67286E-11
3.3597	24.5	100.	3.756	0.014206	0.003782	0.78920E-12
3.3597	24.5	50.	3.764	0.015360	0.004081	0.42667E-12
3.3597	24.5	10.	3.773	0.017836	0.004727	0.99091E-13
3.0945	50.0	10.	3.778	0.022700	0.006009	0.12611E-12
3.0945	50.0	50.	3.760	0.017612	0.004684	0.48922E-12
3.0945	50.0	100.	3.753	0.016253	0.004331	0.90296E-12
3.0945	50.0	1000.	3.745	0.012819	0.003423	0.71214E-11
3.0945	50.0	10000.	3.727	0.009887	0.002653	0.54927E-10
3.0945	50.0	100000.	3.710	0.008623	0.002324	0.47904E-09
3.0945	50.0	1000000.	3.695	0.010598	0.002868	0.58876E-08
3.0945	50.0	9500000.	3.651	0.015408	0.004220	0.81320E-07
3.0945	50.0	30000000.	3.623	0.011837	0.003267	0.19729E-06
2.6799	100.0	30000000.	3.631	0.012888	0.003549	0.21481E-06
2.6799	100.0	9500000.	3.666	0.012966	0.003537	0.68429E-07
2.6799	100.0	1000000.	3.695	0.008235	0.002229	0.45748E-08
2.6799	100.0	100000.	3.705	0.008922	0.002408	0.49569E-09
2.6799	100.0	10000.	3.726	0.012396	0.003327	0.68866E-10
2.6799	100.0	1000.	3.742	0.016426	0.004390	0.91257E-11
2.6799	100.0	100.	3.764	0.024341	0.006467	0.13523E-11
2.6799	100.0	50.	3.774	0.031256	0.008282	0.86823E-12
2.6799	100.0	10.	3.803	0.054660	0.014374	0.30367E-12
2.3632	150.0	10.	3.839	0.092246	0.024028	0.51248E-12
2.3632	150.0	50.	3.790	0.044838	0.011829	0.12455E-11
2.3632	150.0	100.	3.778	0.032946	0.008719	0.18303E-11
2.3632	150.0	1000.	3.744	0.020960	0.005598	0.11644E-10
2.3632	150.0	10000.	3.727	0.015101	0.004052	0.83893E-10
2.3632	150.0	100000.	3.706	0.012757	0.003442	0.70872E-09
2.3632	150.0	1000000.	3.677	0.008623	0.002345	0.47904E-08
2.3632	150.0	9500000.	3.652	0.013743	0.003763	0.72534E-07
2.2314	175.0	30000000.	3.614	0.017161	0.004749	0.28601E-06
2.2314	175.0	9500000.	3.603	0.009362	0.002599	0.15603E-06
2.2314	175.0	1000000.	3.633	0.013707	0.003772	0.72341E-07
2.2314	175.0	100000.	3.682	0.017763	0.004830	0.98792E-08
2.2314	175.0	10000.	3.697	0.020848	0.005639	0.11582E-08
2.2314	175.0	10000.	3.726	0.026165	0.007022	0.14536E-09
2.2314	175.0	1000.	3.761	0.025904	0.006888	0.14391E-10
2.2314	175.0	100.	3.799	0.041062	0.010809	0.22812E-11
2.2314	175.0	50.	3.812	0.053381	0.014004	0.14828E-11
2.2314	175.0	10.	3.865	0.092537	0.023944	0.51409E-12
2.1135	200.0	10.	6.776	1.172523	0.173032	0.65110E-11
2.1135	200.0	50.	5.528	0.987350	0.178601	0.27426E-10
2.1135	200.0	100.	5.088	0.858599	0.168743	0.47700E-10
2.1135	200.0	1000.	4.221	0.401071	0.095028	0.22282E-09
2.1135	200.0	10000.	3.892	0.161689	0.041549	0.89827E-09
2.1135	200.0	100000.	3.767	0.073601	0.019337	0.40889E-08
2.1135	200.0	1000000.	3.683	0.036921	0.010025	0.20512E-07
2.1135	200.0	9500000.	3.617	0.030299	0.008377	0.15991E-06
2.1135	200.0	30000000.	3.571	0.022495	0.006300	0.37491E-06

"Udell" P-8000, continued

T°C	Freq., GHz	1	1.685	2.45	3	5	8.515
25	K	3.590	3.569	3.556	3.550	3.538	3.527
	D.F.	.00410	.00420	.00428	.00432	.00438	.00435
75	K	3.575	3.558	3.547	3.542	3.527	3.515
	D.F.	.00471	.0049	.00503	.00504	.00496	.00480
125	K	3.562	3.545	3.532	3.527	3.511	3.486
	D.F.	.00495	.00518	.00538	.00555	.00582	.00576
175	K	3.543	3.52	3.517	3.510	3.495	3.472
	D.F.	.00520	.0056	.0060	.0063	.0067	.0069

Printed Circuit Boards

Union Carbide

Polyimide laminate, 11848-12-3

T°C	Freq., Hz	10 ³	100	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ⁸	10 ⁹	10 ¹⁰
		10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ⁸	10 ⁹	10 ¹⁰	10 ⁹	10 ¹⁰
24.2	x	5.141	5.122	5.075	5.044	4.972	4.898	4.789	4.68	4.65	4.57
	tan δ	.00577	.00510	.00459	.00553	.00994	.0156	.0194	.022	.0124	.0147
50	x									4.67	4.58
	tan δ									.0138	.0196
100	x									4.66	4.59
	tan δ									.0144	.0229
150	x									4.66	4.593
	tan δ									.0144	.0263
175	x									4.65	4.577
	tan δ									.0143	.0319
200	x	7.560	5.797	5.191	4.988	4.929	4.830	4.759	4.71	4.64	4.516
	tan δ	.422	.1488	.0525	.0182	.00994	.00736	.00820	.0108	.0138	.0346
175	x	5.519	5.149	4.971	4.874	4.815	4.75	4.717	4.68	4.63	4.54
	tan δ	.110	.0510	.0215	.0112	.00792	.0065	.00939	.0114	.0136	.0314
150	x	5.325	4.983	4.884	4.814	4.765	4.730	4.675	4.63	4.61	4.55
	tan δ	.0534	.0265	.0127	.00835	.00624	.0070	.00924	.0113	.0130	.0255
100	x	4.951	4.850	4.793	4.750	4.717	4.671	4.624	4.60	4.58	4.514
	tan δ	.0121	.00844	.0067	.00529	.00476	.0066	.0104	.0108	.0117	.0212
50	x	4.823	4.725	4.709	4.684	4.660	4.609	4.544	4.50	4.55	4.451
	tan δ	.00547	.00691	.00429	.00411	.00557	.00795	.0109	.0098	.0097	.0169
25	x	4.786	4.695	4.682	4.659	4.621	4.547	4.503	4.46	4.51	4.413
	tan δ	.00322	.00389	.00396	.00456	.0069	.00841	.0108	.0110	.0086	.0133

Polyolefin, crosslinked, 11848-12-2

T°C	Freq., Hz	10 ³	100	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ⁸	10 ⁹	10 ¹⁰
		10 ³	100	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ⁸	10 ⁹	10 ¹⁰
24	x	2.91	2.89	2.869	2.845	2.814	2.771	2.761	2.757	2.847	2.842
	tan δ	.00322	.00435	.0053	.00644	.00668	.03704	.00735	.0076	.00254	.00664
50	x									2.860	2.828
	tan δ									.0103	.00807
100	x									2.845	2.796
	tan δ									.0163	.0117
150	x									2.877	2.778
	tan δ									.0236	.0170
175	x									2.861	2.759
	tan δ									.0276	.0205
200	x	3.229	3.046	3.002	2.884	2.790	2.715	2.688	2.59	2.778	2.756
	tan δ	.438	.0633	.0265	.0310	.0134	.0132	.0212	.0272	.0303	.0216
175	x	3.226	3.216	3.045	2.923	2.872	2.812	2.731	2.65	2.779	2.757
	tan δ	.1324	.0334	.0345	.0183	.0131	.0177	.0211	.0232	.0248	.0200
150	x	3.219	3.067	2.967	2.936	2.883	2.824	2.740	2.69	2.781	2.782
	tan δ	.0467	.0345	.0165	.0117	.0104	.0166	.0188	.0211	.0225	.0165
100	x	3.012	3.005	2.978	2.931	2.874	2.821	2.766	2.72	2.805	2.801
	tan δ	.00247	.00417	.00859	.0115	.0128	.0137	.0139	.0136	.0130	.0104
50	x	2.817	2.807	2.796	2.773	2.767	2.704	2.705	2.695	2.806	2.802
	tan δ	.00650	.00645	.00554	.00554	.00557	.00658	.00742	.0084	.00815	.00686
25	x	2.824	2.820	2.814	2.805	2.789	2.767	2.743	2.73	2.804	2.802
	tan δ	.00200	.00251	.00294	.00336	.00402	.00510	.00618	.0066	.00632	.00538

Printed Circuit Boards, continued

Union Carbide

Polysulfone P-1700, 11848-12-1

T°C	Freq., Hz	10	100	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ⁸	10 ⁹	10 ¹⁰
24	x	3.203	3.186	3.173	3.157	3.152	3.141	3.094	3.06	3.043	3.025
	tan δ	.00111	.00132	.00157	.00240	.00448	.00610	.0106	.0197	.0063	.00652
50	x									3.05	3.031
	tan δ									.00702	.00749
100	x									3.05	3.029
	tan δ									.00785	.00878
150	x									3.06	3.016
	tan δ									.0087	.01154
175	x									3.03	2.983
	tan δ									.0095	.0122
200	x	5.48	4.30	3.59	3.35	3.21	3.16	3.13	3.08	3.02	2.977
	tan δ	.293	.186	.0923	.0413	.0199	.0094	.0087	.010	.0148	.0132
175	x	3.22	3.22	3.20	3.14	3.12	3.10	3.09	3.07	3.01	2.977
	tan δ	.00929	.00756	.00720	.00952	.00342	.00371	.00411	.0064	.04962	.0139
150	x	3.21	3.18	3.14	3.11	3.10	3.09	3.08	3.06	3.03	2.993
	tan δ	.00371	.00787	.00853	.00407	.00317	.00270	.00333	.0052	.0082	.0108
100	x	3.09	3.08	3.08	3.08	3.08	3.07	3.07	3.05	3.01	2.977
	tan δ	.00073	.00064	.00057	.00065	.00094	.00158	.00303	.0042	.0055	.00783
50	x	3.09	3.08	3.08	3.08	3.07	3.07	3.06	3.05	3.00	2.969
	tan δ	.00041	.00054	.00068	.00095	.00141	.00223	.00352	.0043	.0046	.00609
25	x	3.097	3.088	3.085	3.080	3.073	3.063	3.056	3.03	3.00	2.966
	tan δ	.00046	.00066	.00096	.00134	.00160	.00256	.00384	.00439	.0041	.00519

At 24°C, 30 MHz, tan δ = .016

Polysulfone P-1720, 11848-12-2

T°C	Freq., Hz	10	100	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ⁸	10 ⁹	10 ¹⁰
24	x	3.252	3.238	3.233	3.222	3.197	3.159	3.141	3.08	3.044	3.032
	tan δ	.00119	.00144	.00226	.00306	.00446	.00774	.00764	.0061	.00366	.00660
50	x	3.23	3.22	3.21	3.20	3.20	3.17	3.13	3.08	3.050	3.034
	tan δ	.00127	.00098	.00125	.00162	.00272	.00555	.00795	.0077	.00656	.01757
100	x	3.19	3.18	3.17	3.17	3.15	3.15	3.14	3.07	3.05	3.015
	tan δ	.00221	.00263	.00193	.00170	.00181	.00287	.00546	.0073	.0078	.00926
150	x	3.27	3.22	3.19	3.15	3.13	3.11	3.10	3.07	3.04	3.006
	tan δ	.00491	.00827	.00777	.00518	.00433	.00379	.00451	.0068	.0086	.0113
24	x	3.11	3.11	3.10	3.10	3.09	3.08	3.07			
	tan δ	.00061	.00081	.00103	.00160	.00237	.00326	.00389			
50	x	3.12	3.09	3.09	3.09	3.09	3.08	3.07			
	tan δ	.00051	.00069	.00081	.00111	.00175	.00284	.00375			
100	x	3.11	3.09	3.09	3.08	3.08	3.08	3.07			
	tan δ	.00111	.00083	.00073	.00084	.00119	.00196	.00319			
150	x	3.24	3.20	3.75	3.13	3.11	3.08	3.08			
	tan δ	.00513	.00958	.00714	.00403	.00371	.00332	.00404			
Freq., Hz											
150	tan δ	.00612	.00926								
175	x									3.01	2.962
	tan δ									.0093	.0129
200	x	4.84	3.84	3.46	3.28	3.20	3.16	3.13	3.08	3.02	2.942
	tan δ	.234	.1285	.0575	.0302	.01147	.00700	.00713	.0079	.0150	.0137
175	x	3.26	3.22	3.19	3.13	3.14	3.11	3.10	3.06	2.95	2.917
	tan δ	.00679	.00703	.01132	.00551	.00306	.00338	.00396	.0060	.00966	.0123
150	x	3.23	3.19	3.14	3.13	3.10	3.10	3.09	3.05	3.00	2.938
	tan δ	.00617	.0104	.00581	.00319	.00360	.00251	.00311	.0056	.00792	.0102
100	x	3.11	3.11	3.10	3.10	3.10	3.09	3.09	3.04	2.99	2.935
	tan δ	.00078	.00062	.00058	.00066	.00088	.00151	.00271	.0042	.00362	.00785
50	x	3.11	3.10	3.10	3.10	3.09	3.08	3.06	3.02	2.98	2.932
	tan δ	.00050	.00055	.00068	.00094	.00144	.00228	.00334	.0039	.00452	.00634
24	x	3.110	3.104	3.100	3.100	3.098	3.087	3.081	3.04	2.98	2.932
	tan δ	.00045	.00073	.00098	.00135	.00195	.00269	.00348	.0035	.00408	.00517

At 200°C, 30 Hz, x = 4.25, tan δ = .1796

Epoxy 2795/2793 with UV stabilizers

Union Carbide
Samples from MIT Lincoln Laboratory

3 GHz R.T.

Stabilizer	K	$\tan \delta$
None	3.11	.0365
Benzotriazole	2.98	.0327
Substituted acrylonitrile	3.09	.0327
Benzidine malonate	3.14	.039
Benzophenone	3.10	.031

Polymer with tungsten wire reinforcement

AFML

25°C

Temperature run 8.5 GHz

Freq., Hz	K	$\tan \delta$	T°C	K	$\tan \delta$
100	8.91	.0117	23	3.032	.0241
1K	8.31	.0459	94	3.142	.049
3K	8.02	.0400	101	3.222	.077
10K	7.72	.0487	130	3.294	.106
300K	6.10	.141	150	3.344	.137
1M	5.71	.160	170	3.376	.156
3.5M	4.69	.168	208	3.428	.184
30M	3.75	.110			
8.5G	3.034	.0253			

Polyurethane Foam CPK 1057-6.24

Upjohn

8.5 GHz R.T. K = 1.122 D.F. = .00241

IV. Liquids

Crude oil, low viscosity

MIT

T°C	T°F	Freq., Hz	10^2	10^3	10^4	10^5	10^6	5×10^6	1.6×10^7	10^8	2.45×10^9	3×10^9
58	136	K	2.667	2.456	2.363	2.327	2.308	2.281	2.278	2.256	2.256	2.238
		$\tan \delta$	2.63	.332	.0541	.0102	.0038	.0030	.0073	.0074	.00495	.0052
		σ	3.9E-10	4.5E-10	7.1E-10	1.33E-9	4.87E-9	3.2E-8	1.5E-7	9.3E-6	1.5E-5	1.9E-5
22	72	K	2.643	2.494	2.407	2.376	2.360	2.333	2.309	2.292	2.290	2.272
		$\tan \delta$	2.68	.0742	.0172	.0061	.0076	.0106	.0115	.0035	.0028	.0029
		σ	6.1E-11	1.E-10	2.3E-10	8.2E-10	1.E-8	6.9E-8	2.3E-7	4.45E-6	8.7E-6	1.1E-5
-20	-4	K	2.563	2.481	2.402	2.392	2.336	2.330	2.318	2.310	2.31	2.31
		$\tan \delta$	.0287	.0146	.0118	.0118	.00909	.00535	.00361	.0007	.0008	.0010
		σ	4.1E-12	2.E-11	1.5E-10	1.5E-9	1.2E-8	3.9E-8	7.4E-8	1.E-6	2.5E-6	3.8E-6

Crude oil, high viscosity

MIT

C536 (Alaskan type) 2%												
60	140	K	3.277	2.903	2.673	2.578	2.548	2.473	2.464	2.333	2.330	2.330
		$\tan \delta$	.285	.37	.0703	.0104	.0169	.019	.0173	.0080	.00584	.0076
		σ	5.2E-10	5.9E-10	1.E-9	1.9E-9	2.4E-8	1.3E-7	3.8E-7	1.E-5	1.85E-3	2.95E-5
28	82	K	3.129	2.820	2.669	2.606	2.511	2.488	2.467	2.396	2.394	2.393
		$\tan \delta$	.397	.092	.0304	.0190	.0190	.0154	.0116	.0050	.0040	.0047
		σ	6.9E-11	1.4E-10	4.5E-10	2.1E-9	2.7E-8	1.E-7	2.5E-7	6.65E-6	1.3E-5	1.9E-5
-18	0	K	2.811	2.670	2.391	2.139	2.495	2.492	2.489	2.37	2.37	2.37
		$\tan \delta$	.0421	.0273	.0178	.0115	.0076	.0050	.0032	.0022	.0021	.0025
		σ	6.6E-12	4.1E-11	2.6E-10	1.6E-9	1.E-8	3.4E-8	7.1E-8	2.9E-6	6.8E-6	1.E-5

Carbon tetrabromide

MIT Materials Science

1 MHz

	T°C	K	D.F.
Liquid	94	2.584	.00069
	102	2.563	.00091
Solid	25	2.468	.0002

Dioctalphthalate C₂₄H₃₈O₄

MIT, Melcher

At 1 to 100 Hz, 23°C $\kappa = 5.15$ $\sigma = 5.74E-12 \text{ mho/cm}$

Water-Hydrochloric Acid Solutions

MIT for JPL

8.515 GHz 24.1°C

Wt% Acid	κ'	κ''	σ	Wt% Acid	κ'	κ''	σ
0	63.5	63.7	.131	25	1.3	151	.713
5	39.5	119	.562	29	2.8	145	.685
10	12.0	162	.765	32	5.8	132	.625
18	-4.8	164	.777	37	9.4	124	.586

Water-Sulfuric Acid Solutions

MIT for JPL

8.515 GHz 24.9 ± .5°C

8.515 GHz 22.8°C

Wt% Acid	κ'	κ''	σ	Wt.% Acid	κ'	κ''	σ
0	67.2	28.3	.134	0	67.0	29.4	.139
1.11	64.0	37.3	.177	31.72	1.3	153	.7225
5.04	50.1	65.9	.312	33.7	2	153.4	.726
10.08	32.0	97.7	.462	35.23	3.2	153.3	.725
15.09	18.1	122	.579	38.06	3.2	149	.704
20.15	6.4	140.5	.665	40.80	6.4	145	.687
25.32	-0.4	152	.720	43.66	9.8	140.4	.664
30.15	-4.1	157.5	.745	47.22	11.3	130.8	.619
35.24	-0.2	157.4	.7445	50.38	16.7	122	.578
40.38	3.8	150.7	.713	52.74	21.8	119	.564
45.31	6.5	137.4	.650	58.37	22.3	106	.502
50.38	17.3	127.3	.602	64.69	32.0	78.6	.372
55.43	23.4	111.4	.527	73.33	30.2	52.6	.249
60.39	25.5	91.9	.435	84.59	29.8	32.7	.155
65.55	29.6	76.4	.362	91.94	28.45	34.5	.163
70.61	24.2	56.2	.266	95.87	26.4	34.6	.164
75.61	29.4	44.4	.210	96.26	24.5	32.9	.159
80.49	29.0	36.1	.171	96.61	23.4	31.1	.147
85.52	26.8	33.7	.159	97.1	22.0	29.6	.140
90.55	28.0	35.6	.168	97.22	21.8	29.9	.141
96.26	23.7	33.6	.159				

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